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PRINCIPLES FOR PROGRAMING LEARNING MATERIALS IN
SELF-INSTRUCTIONAL DEVICES FOR MENTALLY-RETARDED CHILDREN.
FINAL REPORT.
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PRINCIPLES FOR PROGRAMING INSTRUCTIONAL MATERIALS FOR TEACHING MENTAL RETARDATES WERE DEVELOPED FROM CONCEPTS DERIVED FROM A THEORY PREVIOUSLY DEVELOPED BY THE AUTHOR. THE THEORY PLACED EMPHASIS ON THE CUEING FUNCTION IN THE STIMULUS CONTROL OF BEHAVIOR. RELEVANT SECTIONS OF THE THEORY AND RELATED RESEARCH WERE DESCRIBED. SEPARATE EXPERIMENTS WERE CONDUCTED FOR (1) GROUPING AND SPACING OF FRAMES WITH COMMON STIMULUS ELEMENTS - RECOGNITION AND RECALL UNDER STIMULUS CONTROL, (2) SEQUENCING COMPLEX ASSOCIATIVE PARADIGMS THAT ARE TAUGHT IN BOTH A FORWARD AND BACKWARD DIRECTION, (3) PROMPTING VERSUS CONFIRMATION SEQUENCES AND OVERLEARNING IN THE AUTOMATED TEACHING OF SIGHT VOCABULARY, (4) PROMPTING, CONFIRMATION, AND VANISHING IN THE AUTOMATED TEACHING OF A SIGHT VOCABULARY, AND (5) APPLYING A COMPUTER-PREPARED PROGRAM FOR AUTOMATED FRAME WRITING. SOME OF THE FINDINGS WERE THAT (1) OPTIMUM SEQUENCE OF MATERIAL FOR THE LEARNER COULD BE CONTINGENT UPON HIS APTITUDES OR ABILITIES, (2) EXPLICIT RULES FOR GENERATING PROGRAMS COULD BE BUILT INTO THE PROGRAMING USED BY THE COMPUTER IN WRITING FRAMES, (3) USE OF A PROMPTING STIMULUS-RESPONSE (S-R) SEQUENCE PRODUCED MORE RAPID LEARNING THAN USE OF A CONFIRMATION S-R SEQUENCE, AND (4) A COM PUTER-PREPARED PROGRAM TO GENERATE INSTRUCTIONAL MATERIALS APPEARED SUCCESSFUL IN PRODUCING A CHANGE IN THE SUBJECT'S ABILITY TO EXPRESS HIMSELF. (RS)

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PRINCIPLES FOR PROGRAMING LEARNING MATERIALS IN SELF-INSTRUCTIONAL DEVICES FOR MENTALLY-RETARDED CHILDREN, FINAL REPORT

Final Report
Cooperative Research Project No. 661
SAE 8370

Lawrence M. Stolurow[1]
University of Illinois
Urbana, Illinois
1963

The research reported herein was supported through the Cooperative Research Program of the Office of Education, U. S. Department of Health, Education, and Welfare

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[1] This work was accomplished during the author's tenure at the Institute for Research on Exceptional Children of the University of Illinois.

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Errata

Page	Line	
7	5	Change 1961 to 1962.
90	12	Change last line of paragraph to read: transfer of the responses taught to the new words.
	19	Delete the word however in this line, adding a period after the word factors.
162	8	Change the parenthetical phrase to read: (for the bigram ranking).
168	7	Change the word case to the word ease.
170	—	Add the following sentence to the footnote: The test of significance is by calculating a t by dividing the beta weight by its standard error.
183	4	Insert the article a before the word critical.
184	13	Add a question mark to the end of the sentence.
185	7	Change the line to read: related to their recall of
	8	Change the line to read: words but not to their recognition of them.
186	—	Delete the letter q in the column headed Recognition 1 day, motor encoding.
187	—	Add the following sentence to the footnote: The test of significance is by calculating a t by dividing the beta weight by its standard error.

PREFACE

The work relating to this project was initiated before support was received from the U. S. Office of Education. Work was accomplished while the author was on a half-time appointment in the Institute for Research on Exceptional Children of the University of Illinois.

The first article published was Automation in Special Education, which appeared in Exceptional Children, 1960. A more comprehensive manuscript reviewing the literature and relating it to some of its basic psychological underpinnings was given to the U. S. Office of Education for publication by the Government Printing Office as Cooperative Research Monograph No. 6 (OE 43010), titled Teaching by Machine, which was issued in 1961. The first paper relating to project work was presented at the 1960 Annual Convention of the Council of Exceptional Children. This paper appeared in Exceptional Children (Stolurow, 1960). The initial studies, relating the concepts of prompting and confirmation as they developed in the psychology of verbal learning, were summarized briefly at the XIV International Congress of Applied Psychology in Copenhagen in 1961 (Stolurow, 1961). A more complete review of this is to appear in a book edited by De Cecco entitled Educational Technology. The same series of studies was reported in part at the meeting of the Council for Exceptional Children in 1962 by Lippert and at the Annual Meeting of the American Association on Mental Defiency in 1962 by Stolurow.

A number of people contributed to the studies and the processing of data. A complete listing is not possible, but certainly the cooperation of the personnel at Lincoln State School, particularly Superintendent Joseph Albaum, Lloyd L. Wolf, Chief of Special Education and William Chambers, Chief Psychologist, is to be acknowledged for their assistance in the initial work of this project. I would like also to acknowledge the interactions which took place in the Institute between Dr. Herbert Goldstein and myself. Hopefully, this was a mutual interchange and certainly it had its effect upon the sight vocabulary studies in terms of the explication of theory. Finally, I would like to acknowledge the support and encouragement given me by Professor Kirk in the early stages of the preparation of the proposal and throughout the execution of the studies. His background of information and experience contributed to the development of the ideas that were tested here. It is hoped that additional concepts and notions which were stimulated by the discussions with Professor Kirk and others at the Institute will eventually be brought to fruition.

Acknowledgment is made of the contributions of several research assistants — Carol Koch, Stanley Peters, Al Ferrier, Gerald Hasterok, G. Phillip Cartwright, Marvin Steinberg, and Henry T. Lippert.

The period during which this work was accomplished was one in which programed instruction was just beginning to become interesting. Skinner's first article appeared in 1954 and stimulated considerable interest in the field which Pressey's work had failed to do. Most programs were linear in format and designed to fit a limited set of preconceptions regarding reinforcement requirements. The studies reported here were out of the mainstream in that they were based upon a theory that gives more emphasis to the cueing function in the stimulus control of behavior. Their purposes were to explore and expand the theoretical notions of stimulus control while also studying learning problems of the mentally retarded.

The present summary of research represents only an initial effort to relate basic concepts of my learning theory to the problems of teaching the mentally retarded. A great deal more can and should be done in this area and the modern developments in educational technology certainly indicate the great potentiality that lies here. This is a particularly important focus for modern educational technology in view of the dearth of competent and motivated teachers, particularly within residential institutions. Fortunately, the sociology of education of the mentally retarded is changing and a greater proportion of them is being taught in special education classes in schools located near their homes. While this is a mixed blessing, it suggests that changes are taking place which could lead to the greater use of new educational media provided quality materials are developed. Additional research is a requisite in order that characteristics of materials can be related to particular patterns of student needs in a way which would accomplish a highly individualized instruction.

This report describes relevant parts of the theory and a set of studies relating to aspects of it. It has, as its primary focus, the application of the "new" technology of education to research on the teaching of retarded students. To make the prose more readable, many qualifications have been eliminated and, in many cases, a description of the general problem has been treated elliptically. The manuscript should be read critically, especially with respect to statements about techniques and methods of programed instruction, since the questions dealt with were initially a biased set, namely those appearing to have most relevance to the teaching of students whose mental age (MA) is less than their chronological age (CA). This is not meant to imply, however, that programed instruction is inherently more useful or effective with the lower half of the intelligence distribution. Two factors argue to the contrary: (1) the results of studies indicate that programs can be written to favor either half of the ability distribution and (2) the program found to be more effective for children whose MA's are only 5 when their CA's are 8, for example, could be effective for the children whose MA's are 5 when their CA's are only 3 or 4. In such cases the program would be effective for gifted students.

One of the important problems in furthering this development is the preparation of materials which can be utilized by individual students regardless of whether they are at home or in an institution. The extent to which these materials can be presented, the appropriate feedback given, and the sequence determined by information about the individual student are potentially important advances. Probably one of the more interesting developments in the use of computers for instruction in special education, particularly with the retarded but also with the aphasic and other special groups, is in its use to generate materials. Through appropriate programing procedures teachers would be in position to specify the needs of individual students in a way which would permit the computer to generate the materials required for each practice period without the teacher having to prepare them. In this way the logic of instruction can be the central factor determining the nature of the instructional material. The details of its implementation can be taken care of by an automated system. Only the beginning of this type of development is described in this report but the results have been sufficiently encouraging to indicate its need and its potential utility.

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Chapter 1

RESEARCH RELATING TO PRINCIPLES FOR PROGRAMING LEARNING MATERIALS IN SELF-INSTRUCTIONAL DEVICES FOR MENTALLY RETARDED CHILDREN

An important but unsolved problem in education is the method of teaching that should be used in order to maximize the rate at which mentally retarded children learn. This is obviously a complex problem which has to be dealt with in terms of its separate facets. One facet about which we know little is the organization, or programing, of teaching materials to promote rapid learning, retention,and transfer. Another facet concerns the important unsolved problems of stimulus control, or guidance, not only to promote learning but also to aid retention,and transfer. Still another basic set of problems relates to the development of concepts and methods for tailoring instructional procedures to individual differences in aptitude and ability.

INDIVIDUALIZED INSTRUCTION

The present research is only an initial effort to delineate and examine the basic problems of individualizing instruction. It was undertaken to determine the usefulness of a set of hypotheses extracted from laboratory research on learning. These hypotheses were chosen because they appeared to be useful in the development of programed learning materials. While there have been many promising efforts to develop psychological theories of learning, there has been relatively little effort to develop the technology of learning which would permit the translation of these theories into educational practices. Programed learning and automated instruction are a promising, potential contribution to the technology of learning which in its more comprehensive and highly developed form is educational engineering. The development of conditions of learning to fit a design based upon an individual's needs would be particularly useful to special education in view of the highly individualized requirements which these students have.

The Research Potential of Programed Instruction

If the individualization of education is a goal of educational technology, then several basic kinds of information are needed so that decisions can be made about the selective use of teaching strategies to accomplish specified educational objectives. In order to generate this type of information, it is necessary to identify relevant variables over which sufficient control can be exercised to permit the establishment of reliable relationships with learning outcomes. In educational research,control over factors that otherwise would confound the effects of an instructional method, such as variations among teachers, has been an obstacle to the identification of significant variables relating to instructional effectiveness. Individualized instruction requires a level of precision in the control of variables that has not been possible by conventional means. Furthermore, potentially useful data,such as the individual responses of students,have not been available for use in evaluating the "fine grain" of instructional procedures.

While the potential importance of programed instruction for advancing the individual student has been pointed out by many, the potential research contribution of this approach to basic problems in the development of a theory of teaching has not been given equivalent attention and recognition even though, in fact, it is a prior condition. Whether or not programed instruction becomes a widely used school method is really less critical at this time than whether or not it takes hold in educational laboratories and is used to its fullest extent for the development of new knowledge about the psychology of teaching and learning. The principles that are revealed by the use of programed self-instruction are not just "machine principles"; if they work and accomplish desired objectives they are principles of teaching in the most general and desirable sense. If a machine can be built to accommodate a program written to conform to a learning principle, then there is a good chance that a teacher can be taught to do the same thing, if that is what is wanted. The more basic problem to be solved is that of developing information and theories about methods for teaching, most effectively, a given subject matter to a learner who has particular abilities, interests and personality characteristics.

Programed self-instruction requires that particular conditions and variables be made explicit. Consequently, once they are formulated sufficiently to be used, they are under adequate control and are stabilized enough to be used with as many groups of students as are desired to determine their effectiveness. For theoretical purposes, different conditions can be used and reused to teach groups in ways that vary systematically from one another. Replicability has a further advantage in that specific defects are revealed in a program. This means that possible ways of eliminating them can be more efficiently discovered. Thus, the good parts of the program can be retained and the weak ones eliminated. The cumulative effect of a consistent effort to develop a set of instructional materials can be expected to be one of demonstrable improvements in student achievement. New educational practices can be discovered and evaluated through an understanding of the basic instructional processes.

PROGRAMED INSTRUCTION FOR THE MENTALLY RETARDED: A REVIEW[1]

Research on programed instruction (PI) for the mentally retarded was reviewed prior to the initiation of this project (Stolurow 1960, 1961). An article and a monograph reviewed both the few PI studies using mentally retarded children and the related issues that were of current interest. Silberman's excellent chapter in the April 1962 Review of Educational Research included several subsequent reports. The earlier studies, based primarily on language programs, indicated that programed instruction was indeed feasible for, and applicable to, educable mentally handicapped (EMH) children and slow learners. Without normative behavioral data based upon alternative methods of instruction, it is not possible to make quantitative comparisons with other methods of instruction. However, the relative efficiency of PI and of other methods is typically less important as an issue in the education of the retarded than in the education of children of average or superior intellectual status. Those who are institutionalized, for example, often have minimal educational opportunities. Hence, any use of effective methods would be helpful.

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[1] Based upon Stolurow (1963).

This chapter attempts to represent the kinds of proposals, plans, and findings that are being developed in this country. It reviews the types of studies, the plans, and findings of the investigators, however tentative and sketchy they may be.

Table 1 lists the 14 projects about which some information has been available. Blanks represent gaps in this writer's information. Of these 14 projects, seven have dealt with language (reading, spelling, language arts); five with arithmetic; and one with each of the following: (a) intelligence and step size, (b) total program for educable mentally handicapped, and (c) inductive reasoning.

Language Studies

In view of the language problems that EMH children have, it is not surprising that PI reading has been a popular topic for research. In spite of decades of research on reading, its nature is not well understood. Hopefully, programed instruction will contribute to our understanding of the learning processes in reading. To data, PI studies have dealt with specific aspects of the total process rather than with all aspects at once. This is typical, since PI research is highly specific. It therefore remains for future work to extend these interesting and promising beginnings to other facets of reading. If the total reading process is considered in terms of some of its major stages, then

Table 1

Studies of Programed Instruction with Mentally Retarded Students[a]

Principal Investigator	Institution	Supporting Agency	Topic
D. Ellson	Indiana Univer.	USPHS	R
M. Woolman	Inst. of Educ. Res.	NIH	R
L. Malpass	Univer. So. Florida	USOE Coop. Res. Br.	RS
J. Price	Partlow Sch.,Alabama	USOE Title VII	A
J. Kleiser	Devereaux Foundation	NIH	A
F. Payne	McFarland Jr. High Washington, D. C.		RSA
J. Birnbrauer	Univer. of Wash.Seattle		TP
L. Stolurow	Univer. of Ill.	USOE Coop. Res. Br.	LA
L. Blackman	Johnstone Trng. Center	USOE Title VII	IR
G. Cartwright	Univer. of Ill.	USOE	A
D. Merachnik	Berkeley Hts., N. J.		A
C. Shay	Univer. of Calif.,L.A.		I & S
Naumann & Woods	Cent. Wash. St. Coll.		S
J. Holland	Fernald St. School		IR

Key:

Topics: R -- reading, S -- spelling, A -- arithmetic, TP -- total program, LA -- language arts, I & S -- intelligence and step size, IR -- inductive reasoning.

[a] A summary of the proposed work on many of these projects is available from the Science Information Exchange, Smithsonian Institution, Washington 25, D. C.

teaching a sight vocabulary is seen as only one stage with two distinguishable aspects: (a) reading aloud and (b) reading silently. Different investigators have worked with each of these aspects.

Picture program in teaching sight vocabulary. Ellson and others (1961), who have been working on a project titled "Machine Teaching of Reading to Retarded Children," have developed a "workable teaching machine program," which has been found to be effective for producing rapid increases in the learning of a reading vocabulary. Their work, summarized in a mimeographed report, indicated that the automation of oral reading poses a technical problem difficult to accomplish. In their own words, the problem is essentially that "machines do not listen well--they cannot distinguish (and thus differentially reinforce) correct and incorrect oral responses with the proficiency required for teaching purposes." Consequently, Ellson and others have used a human listener to simulate a machine. In fact, the listener serves some other related functions; however, since most of his behavior is determined by the program, he can be called a "programed tutor."

In one study, in which 38 retardate residents of Fort Wayne State School participated and in which both experimental and control groups took part, 82 words were selected from A Reading Vocabulary for the Primary Grades prepared by Gates (1935). Each word was paired with a picture, which the children were to name correctly. The statistically significant mean gain was 11.8 words in favor of the experimental group. At the end of one month, there was a 43 percent loss in performance.

To determine the generalization of the programed instruction, a 150-word vocabulary test was developed by selecting every tenth word from the Gates list and by arranging each in order of difficulty, with words employed in the program excluded. The test was administered before and immediately after a five-trial learning session. The experimental group gained, on the average, 7.1 words ($p < .05$); the control group, 2.8 words ($p < .20$).

The program was branched in teaching each word -- intra-item programing -- but the words themselves were not placed in sequence according to any programing rule -- inter-item programing. The intra-item arrangement is a sequential decision procedure: In Step 1, a word is shown, and, if the oral response is correct, the subject is reinforced by a flashing light, and the next word is shown through use of the same procedure. However, if the response is incorrect, Step 2 follows. Step 2 involves showing the word with a picture (prompt). If the oral response is correct, Step 3 follows. However, if the oral response is incorrect, the tutor names the picture correctly, the learner names the picture, and then the learner proceeds to Step 3. In Step 3, the picture is removed (vanished), leaving the word visible by itself. If the oral response is correct, the subject is reinforced and the next word is shown, as in Step 1. If the response is incorrect, the tutor names the word correctly (prompt), the learner does the same, and the next word is then shown (Step 1).

Use of retarded tutors. A second experiment was an informal test of the feasibility of using retarded children as tutors of others. Two retarded children, in approximately two hours, were taught without difficulty to administer the picture program used in the above experiment. The tutors, who had IQ's of 71 and 58, were 14 and 17 years of age, respectively. One taught another child seven words; the other taught four other retarded children a mean of 28 words. The average learning rate was "23 words per hour." Certainly the method is potentially valuable, particularly for institutional use.

Sentence program using verbal prompts. A "sentence program," developed and tested with three groups for eight sessions, used consecutive sentences in a story for primary readers. Like the picture program, a correction procedure or "part method" was used that provided a branch program in a sequential set of five decisions. In Step 1, the sentence is shown. If it is read correctly, the tutor reinforces the subject, who then proceeds to the next sentence. If the sentence is incorrectly read (error in reading any word), the tutor goes to Step 2. In this step, the tutor reads the sentence, then shows each word in the sentence in a random order A by pointing to each one. If the word is read correctly, the tutor reinforces the subject, and the learner goes to Step 3. If any word is read incorrectly, the tutor reads it to the subject, who first repeats it and then proceeds to the next sentence and follows the Step 1 procedure. If incorrect (error in any word), the learner proceeds to Step 4 in which the sentence is shown. The tutor reads the sentence and, leaving the sentence visible, names words of that sentence one at a time in a random order B (different from Step 2); the learner points as the tutor reads. If all words are pointed to correctly, the learner proceeds to Step 5. If any word is not indicated correctly, the tutor points correctly, and then the learner points. After the last word, the tutor has the learner proceed to Step 5, in which the sentence is shown. If it is orally read correctly, the tutor reinforces the learner, has him proceed to the next sentence, and initiates the Step 1 procedure. If an error in any word occurs, the tutor reads the word orally, and the learner repeats it. After the last word, the tutor proceeds to the next sentence and uses Step 1.

The program was used in eight one-half hour sessions, two per week for four weeks, followed one month later with a retention test. Three groups, each consisting of four children, were taught with this program: (a) normal first graders; (b) slow first grade readers; and (c) retardates (like those in the first experiment). Normals gained, on the average, 30.5 words; slow learners, 20.0; and retarded children, 19.5 words. Mean rates were five words per hour for retarded and slow children; 7.5 for normals. Retention was nearly 90 percent for all groups after one month.

Comparison of classroom and programed learning techniques. Four groups of 16 retarded children were used: (a) program--taught individually with sentence programs; (b) class--taught same material by usual classroom procedures with groups of eight children; (c) alternation--

taught in alternate sessions of program and classroom procedures; and (d) control--no training between tests. Pretests and posttests of reading vocabulary and of comprehension (meaning of sentences) were given to all groups. The mean vocabulary gains were 32.9, 18.1, 37.6, and 6.6, respectively. Differences in mean gain between control and program groups, between control and alternation groups, and between class and alternation groups were significant. No significant comprehension gains were obtained.

The procedures of alternation and program also were compared after an additional six sessions that yielded a total of four sessions per week for three weeks. Results from the posttest given after the 12th session showed that all groups gained significantly more than the control sample. Furthermore, the gain in comprehension was significant for the alternation group only. At the time of the final comprehension test, the subjects in the control group read correctly 25 percent of the words; the program and class groups averaged 33 percent; and the alternation group, approximately 50 percent.

Present plans call for revision of the programing procedure to restrict practice to words not read correctly rather than to all words in sentences in which an error occurs.

Word learning. In Wechkin's (1962) study, the relative efficiency of four conditions, made up of combinations of auditory and visual modes of presentation, were studied. He used 32 delinquent institutionalized girls. Their minimum IQ was 90, and their ages ranged between 14 and 17 years. An auditory cue stimulus, coupled with visual response alternatives, did produce significantly faster learning ($p < .001$), and subsequently better retention, than did auditory response alternatives to visual cue stimuli. Results were interpreted to support the differential fading of the cue stimulus trace. Thus, the findings suggested that programs for the retarded should not remove the cue stimulus before the learner makes a response, especially during early trials.

Research has been conducted at the Edward R. Johnstone Training and Research Center in Bordentown, New Jersey, (Blackman and Smith, 1964) relating to the course that instruction should follow in the very beginning of reading, in that attention has been directed toward four "basic skills:" (a) sight word recognition, (b) sight word meaning, (c) phonics, and (d) comprehension. Over 300 programs in word recognition, sentence recognition phonics, and story comprehension were developed. Machines were developed according to specifications for use at Bordentown in two experimental rooms of 10 children each. During the remainder of the 1962-63 school year, an evaluation of the effectiveness of the programs was made in terms of learning as well as retention. Basic data relating to learning and retention also were collected while the classroom demonstration study was taking place. For example, learning and skill in transfer of printed letter-sound associations, as well as the effectiveness of a minimum versus a maximum change in programing training materials were studied and evaluated.

Spelling. Naumann and Woods (1962) have made a preliminary report of an automated basic spelling program for EMH children. Three boys and three girls in a special education program (whose chronological age varied between 10 years, 1 month, and 16 years, 2 months, and whose Wechsler Intelligence Scale for Children IQ's ranged between 59 and 74) were taught 62 words from representative spelling lists with 15 Skinner-type program units, which varied in length from 25 to 34 frames. Teaching machines were used. All children were given selected parts, including spelling, of the Gates Reading Diagnostic Tests before starting and after completing the program.

All children showed some gains on the spelling tests. Observations indicated (a) the child should always write the whole word, not just the missing part; (b) it was preferable to write programed instruction units in story form; (c) children responded favorably to programed instruction; (d) machines had "play appeal"; and (e) basic training in phonics should be emphasized in pupil's readiness experiences.

Arithmetic Studies

Working with 36 retarded children at Partlow State School for Mental Deficients, Price (1962) compared one group whose answers were constructed with another group taking the same program under multiple-choice conditions. He also included a conventionally instructed control group. The samples were equated for chronological age, mental age, IQ, and arithmetic achievement level. The linear program constructed for the study contained 3,635 problem frames including counting (59 frames), addition (1,107 frames), subtraction (629 frames), arithmetic sign discrimination (100 frames), and mixed addition and subtraction

(1,740 frames). The material was presented through use of a machine. Two tests, in which children responded orally to problems presented to them both visually and orally, were designed to measure progress. Each test consisted of 43 addition and 24 subtraction problems.

Both programed instruction and conventional teaching produced significant improvements. The multiple-choice method resulted in significant improvement in subtraction; however, no significant improvement was observed either for the group that constructed its answers or for the group that received conventional teaching. Addition appears to be teachable to EMH children with either type of PI materials. The two groups receiving programed instruction spent only 86 class periods on the material, whereas the conventionally taught group spent 130 class periods.

Research on programed instruction with arithmetic materials not only has indicated that the method is feasible but also has suggested that it might be more efficient than many of the alternative methods of instructing EMH children. Studies of methods of programing and of the relationships between type of programing method and various aptitudes appear to be among the most promising possibilities for future research. Repetition in programed instruction seems to facilitate learning and to augment retention. The academic use of programed instruction might well consider allowing time for repetition of task material whenever possible. Although there seems to be a general effort to secure retention data as well as learning scores, too few attempts have been made to determine transfer effects. Relatively few studies are being designed to test hypotheses concerning the learning process or to increase the knowledge of professional personnel concerning the special needs of selected subgroups within various segments of the general ability range with divergent thinking abilities.

Intelligence and Step Size

Shay (1961) studied the relationship between level of intelligence and three different sizes of step for a fourth grade unit in the teaching of Roman numerals. Ninety fourth graders in four Los Angeles elementary schools were used. In terms of IQ scores, one-third of the children were at or above 110; one-third, between 93 and 109; and another third, at or below 92.

The results supported Skinner's position to the effect that one program can serve different ability levels. At all three levels of ability as size of step decreased there was an accompanying increase both in posttest score and in time required to complete the program.

Inductive Reasoning

Holland (1962) reported briefly on studies in progress which are potentially promising. Through use of a specially constructed device, visual displays are presented to the subjects as sequences of forms. The child is asked to press a button at the bottom window to indicate which form is to be added to the series on the right extreme. By various grouping plans, different logical operations can be displayed (without the use of language) simply by manipulating color and form of the objects in the sets.

Automated Curriculum

Birnbrauer (1962) has described an entirely "programed" classroom for the EMH. The "programed learning classroom" was established to develop effective and efficient teaching procedures and programed materials to cover the current curriculum for EMH. The curriculum includes "reading, writing, arithmetic, communication, and a number of practical subjects and skills." Each learner attends class for 1.5 hours daily. Usually the students work at a machine, customarily at their own rate. Some commercial programs are being used with a multiple-choice format, since the children cannot write.

Programs and procedures are constantly being revised. Experience suggests that an entirely programed classroom for retardates is feasible.

Summary

In summary, programed instruction for retardates is clearly feasible. Programed instruction needs to be used to determine the special educational requirements of the retarded. It may be more efficient than the alternatives presently available, particularly in institutions. Work is needed on the factors that make it most effective for learning and transfer. The studies conducted thus far reveal a developing rapproachment between the psychology of learning and educational practice. Hopefully, programed instruction will continue to be a catalyst in effecting applications of the psychology of learning to teaching activities.

Chapter 2

THEORY, PROBLEMS, AND PURPOSE

THEORY

Micro-Analysis

Some basic functions. Instructional materials can be considered as having a "fine grain" which has important implications for guiding learning. A conception of the fine grain characteristics of learning materials that seems useful in operationalizing instructional strategies, especially programing, is one that uses a systems approach to the problem (see Stolurow, 1961; 1962; 1964). A basic set of functions can be identified for the events comprising the learning experience, and these are directly relatable to the objectives of instruction. Thus, the functional description of a learning environment implied in a systems approach makes for continuity in the development of materials for instructional purposes.

One set of functions are those relating to stimulus events. One of these, the cue-function, is associated with the most molecular learning situation. The stimuli that provide a cue function attract the learner's attention initially and later become the occasion for a desired response. Thus cue-stimuli are attachable, but not attached, to the desired response. Any individual or set of characteristics of a stimulus, e.g., its onset, duration, or qualitative features, can serve as the cue function in a learning task. The feature or set of features that actually provide this function (regardless of individual or set of characteristics of a stimulus can serve the cue function in a learning task. The feature or set of features that actually provide this function (regardless of the teacher's intentions), are those that are salient and most contiguous with the response.

Another, often related, stimulus function is the elicitation of the response. Many stimulus events are capable of reliably producing the desired response. Consequently, they can be used for this purpose so as to insure its occurrence in contiguity with a cue-stimulus. Ordinarily this is a temporary function in that it would be dispensed with as learning proceeded. Language is particularly useful as a source of eliciting stimuli and it is generally used in accordance with the nature of the desired response and then eliminated except when the responses do not meet performance standards, in which case it is reintroduced.

A third stimulus function is provided by events that follow the response. It is the reinforcement function, i.e., it increases the probability of the same response following the cue-stimulus; however, at least three more specific functions seem to be included in the set called reinforcement: (a) the punctuation of the learning experience; (b) the alternation of a drive, need, or expectancy; and (c) the information function or the introduction of a new cue and/or elicitor. Usually this set of three functions, or some combination of two of them, is provided by a single event. Any, or all, of these functions may be either automatically provided through the response mechanism used or behavior that occurs, or artificially by the way the learning environment is designed. The feedback provided when parts of the body are moved is an example of the automatic condition; the teacher telling the student he should move his body in a certain way when performing an act of skill is an example of the artificial condition. Both the automatic and the artificial conditions have the same effect; namely, to make a type of feedback contingent upon the student's response.

Formation of associative sets. One way in which sets of instructional materials can be varied is with respect to their class-descriptive features. A class-descriptive feature is a characteristic of the individual items (e.g., frames) which make up a set of materials and which could provide the student with class-descriptive cues. Any feature or characteristic of a complex stimulus that is common to two or more, but not all, of the stimuli that are the occasions for the different responses comprising a learning task is a class-descriptive cue. For example, color, shape, position, or size of stimulus objects may be class-descriptive features which could function as cues in a learning task involving these objects. For example, a set of frames in an arithmetic program may use the fraction "1/2" and illustrate it with a candy bar. In one frame with this content the concept of division might be taught, with another the definition of "1/2", and with a third the concept of identify. Another series of frames could follow this one, but use the fraction "1/3". Another possibility would be a sequel that contained "1/2" but used a different object or vehicle for illustration, e.g., a ruler.

In examining a set of learning materials arranged in a sequence, it is possible to identify cue-stimulus redundancies, repetitions, or patterns. These are class-descriptive features and could be class-descriptive cues if the learner utilizes them. Wulff and Stolurow (1957) and Stolurow (1956) have shown that students will, in fact, use such features as cues even though they are neither necessary nor sufficient for correct response. Thus, they can serve as a linking mechanism for otherwise independent learning experiences. A mechanism such as redundancy of stimulus features, can serve a dual purpose. One purpose is to interrelate separate learning experiences into larger or more molar, and often more complex, behavioral segments. Another is to subdivide a long task into sub-tasks. For example, if a set of objects consisted of five red circles, with diameters that varied from 1 to 5 inches, and five blue circles with diameters that varied from 15 to 20 inches, then color would be a class-descriptive feature that could be used to group the displays so that the student could learn their names. When used in this way, color could provide class-descriptive cues that would group each set, but it also would divide the total set into two sub-tasks.

In addition to the use of redundancies to sequence learning materials, it also is possible to use the relationships between pairs of features. When complex stimulus materials are considered as aggregates or sets of separable features (i.e., features that are individually capable of eliciting a distinctive response), then each feature in a display can be the same or different in the display that follows. In an arrangement of stimulus objects, the color, size, or shape, for example, can either change or remain the same as the student sees one object and then another. Also color may remain the same while size changes; for example, a sequence of coins might be arranged so that the first and second were silver color (no change) but the first was smaller than the second (changed). The concept of asynchrony refers to the fact that one feature is the same in going from one object to the next while another feature of these objects changes. The features can be said to be synchronous whenever they both change or whenever they both remain the same, e.g., two successive frames contain nickles. Thus asynchrony/synchrony can be considered the general concept of which the class-descriptive cue arrangement of materials is a special case. It is the case in which one feature of the stimulus material is used to provide redundancy and one or more other features are asynchronous with it.

PROBLEMS

The general problem of teaching in different ways so as to fit individual differences can be studied with a variety of approaches. The general problem is one of major importance and scope, and a short-term research effort can only scratch the surface of it. To do even this, however, it is necessary to develop and use a strategy. In the present case, the strategy used began with an analysis of existent studies of learning to identify some potentially effective principles which could be directly related to the programing of self-instructional materials. To do this, the materials and the process of teaching in general were examined to identify some specific problems that could be studied under relatively controlled conditions. Three problems were identified and proposed for study. During the course of research, a fourth basic problem area was identified and included in the research. This led to a reduction of work on some of the problems originally proposed, since no additional funds were requested for this work. The following four problems were involved in this project.

Amount of change in a program sequence. One persistent problem in teaching is that of organizing the materials to be taught. This problem can be looked at in different ways and in different contexts. In the present study, the organization of material was examined within the context of teaching mentally retarded children the behaviors that are involved in arithmetic and spelling.

Since the concepts involved are most easily described in the context of teaching spelling, it will be used rather than arithmetic which was the area actually studied. In teaching spelling, for example, at least one of the teacher's tasks is that of developing organized response sequences that are eventually used as components of larger behaviors, e.g., spelling words when writing sentences. One way in which the problem that is involved in establishing these elementary sequences can be brought into focus is to consider the changes in the letter sequences that would occur in going from one word to the next word within a list of words. When looked at in this way the ordered set of letters in one word can be related to the ordered set in the next word. Consequently, different letters, or different numbers of responses, can be required in going from one word to the next depending upon the sequence of the words presented to the student. For example, in the sentence PIG, WIG, WAG, WAY, SAY, STY (See Stolurow, 1962), only one letter was changed in going from one word to the next word but the list goes from PIG to STY so it is possible to rearrange the same words so that a larger number of changes occurs from word to word. All the letters of the second word might be different from the letters of the first word, or only one might differ and all the others remain the same. Similarly their order might be changed or preserved to different degrees. When looked at from this point of view, an objective way of scaling the task of learning a list of spelling words becomes available. More specifically, at one extreme in programing a word list the order could be one that maximized the number of changes while at the other extreme, the word order could be one that minimized the number of changes, e.g, bee, see, fee. Between these extremes are different degrees of change. Each of several different degrees of change can be produced by using different sequences in presenting the same set of words. Differently ordered lists of the same words also can produce the same degree of change.

The broader educational problem represented by this analysis of spelling lists, of course, is "step size" and the approach implied by this analysis is in terms of the stimulus properties of the materials to be learned. In other words, size of step is related to the amount of change that takes place in going from one frame to the next. This is a relational concept of step size rather than an absolute one as implied in most other treatments of the concept. The analysis of spelling lists in terms of letter changes is only one of the characteristics of the words that might be considered in scaling step size within a list. Another could be the phonic elements.

The addition and multiplication tables represent equally good examples of materials that lend themselves to the kinds of variation in sequence just described. To illustrate the principle of stimulus change in the context of arithmetic, consider a *minimal* change sequence such as 1 + 1 = 2; 1 + 2 = 3; 2 + 1 = 3; 2 + 2 = 4; 2 + 3 = 5; 3 + 2 = 5; 3 + 3 = 6; 3 + 4 = 7; 4 + 3 = 7; 4 + 4 = 8; 4 + 5 = 9; 5 + 4 = 9; 5 + 5 = 10; etc., and a *maximal* change sequence such as, 1 + 1 = 2; 3 + 4 = 7; 4 + 5 = 9; 1 + 2 = 3; 5 + 5 = 10; 2 + 2 = 4; 3 + 2 = 5; 5 + 4 = 9; 3 + 3 = 6; 4 + 4 = 8; 2 + 1 = 3; 4 + 3 = 7; 2 + 3 = 5, etc. In the former sequence only one or two numbers change in going from problem to problem, whereas in the latter sequence either every number or every number but one changes.

A problem of interest is whether the number of changes in adjacent items in a list is related to the rate at which the lists are learned or to the retention of materials taught.

In programing for self-instructional devices, small steps are frequently considered to be the most desirable for achieving rapid learning. However, whether small steps are desirable or not is an open question as long as there is no agreed upon *a priori* means by which size of step can be determined. The size of a set of steps is seldom defined objectively in advance of the use of a program. Consequently, step size is a dependent variable, e.g., the percentage of error incurred by a group of students, rather than an independent variable. As long as one does not know whether a step is small or large until after students have used the program, the concept does not contribute to the preparation of programed materials. Therefore, it would seem desirable to have a set of defining operations for use by programers to differentiate between two sequences of frames in terms of their step size.

The specification of step size in terms of the relative number of changes made in the critical characteristics of the stimulus -- both cue stimulus and eliciting stimulus -- is not conventional now. On the other hand, there have been a few studies of stimulus sequencing that have taken into account the number of changes between successive stimulus presentations. These studies have indicated that this notion has some utility (Detambel and Stolurow, 1956; Stolurow, 1956). Furthermore, certain "effective" educational materials are known to conform to the minimal change condition, e.g., Kirk and Hegge (1940) remedial reading drills, and Bloomfield's (1961) word lists.

Programing to build multiple association linkages. Another problem in teaching is the building of multiple association linkages. For example, a frequent educational objective is to teach a child to associate a set of words such as "chair," "table" and "desk" with a common word such as "furniture" (object-class relationships). This paradigm can be distingiushed from that in which the object is to develop the association of the sound of the spoken word "chair," as heard when pronounced by the teacher, with the spelling response involved in writing the individual letters in a proper sequence. The latter is a one-to-one association linkage. However, the object-class paradigm, as illustrated above, is a many-to-one association linkage. It is only one form of multiple-association linkage paradigms which are characterized by the requirement to relate a specific set of elements with each other in such a way that either (a) any one of a set of alternative cue stimuli will elicit a particular response, or (b) any one of a set of alternative responses will be elicited by a particular cue-stimulus or from context to context. Another example of the many-to-one paradigm is learning the synonyms of a word either in the same language or in different languages. In the many-to-one association paradigm there are many cue stimuli each of which is an occasion for a response that they share in common.

Other paradigms also involve multiple, but specific, association linkages. One of these is a one-to-many paradigm, the opposite of the many-to-one paradigm. An example of the one-to-many paradigm is factoring a number such as 12. The cue stimulus might be "What are the factors of 12?" ; the responses could be 12 and 1, 6 and 2, 4 and 3. Another example, is learning the definition of a technical term. Typically, definitions are taught both in verbal and symbolic form as in statistics, physics or chemistry. Each definition is a separate but equivalent response to a particular cue stimulus.

At least two separate, but related, programing problems emerge from an analysis of school learning tasks that involve complex sets of associations. One of these can be illustrated by teaching a child to use language in analyzing complex perceptual materials. The teaching problem is that of presenting perceptual materials (e.g., pictures of objects) to the child in such a way that he learns to describe them in terms of classes of component features. Two programs can be used to present these materials to the child. In one, the child sees a picture of one farm animal, for example, and its component features are pointed out to him. For each animal, the features may be the head, body shape, and tail (e.g., of a dog; see Figs. 1 and 2). In another the child sees a very different set of pictures -- one containing only the heads of the animals, another their bodies, a third their coats, and a fourth their tails. In the first program, the object is presented and its components pointed out; in the second program, the components are assembled for presentation as a class of features. For convenience, the first type of organization can be designated as the object-component method of programing, and the second as the class-descriptive features method of programing. The educational problem to which this research pertains is the determination of which these two principles produces the most effective learning.

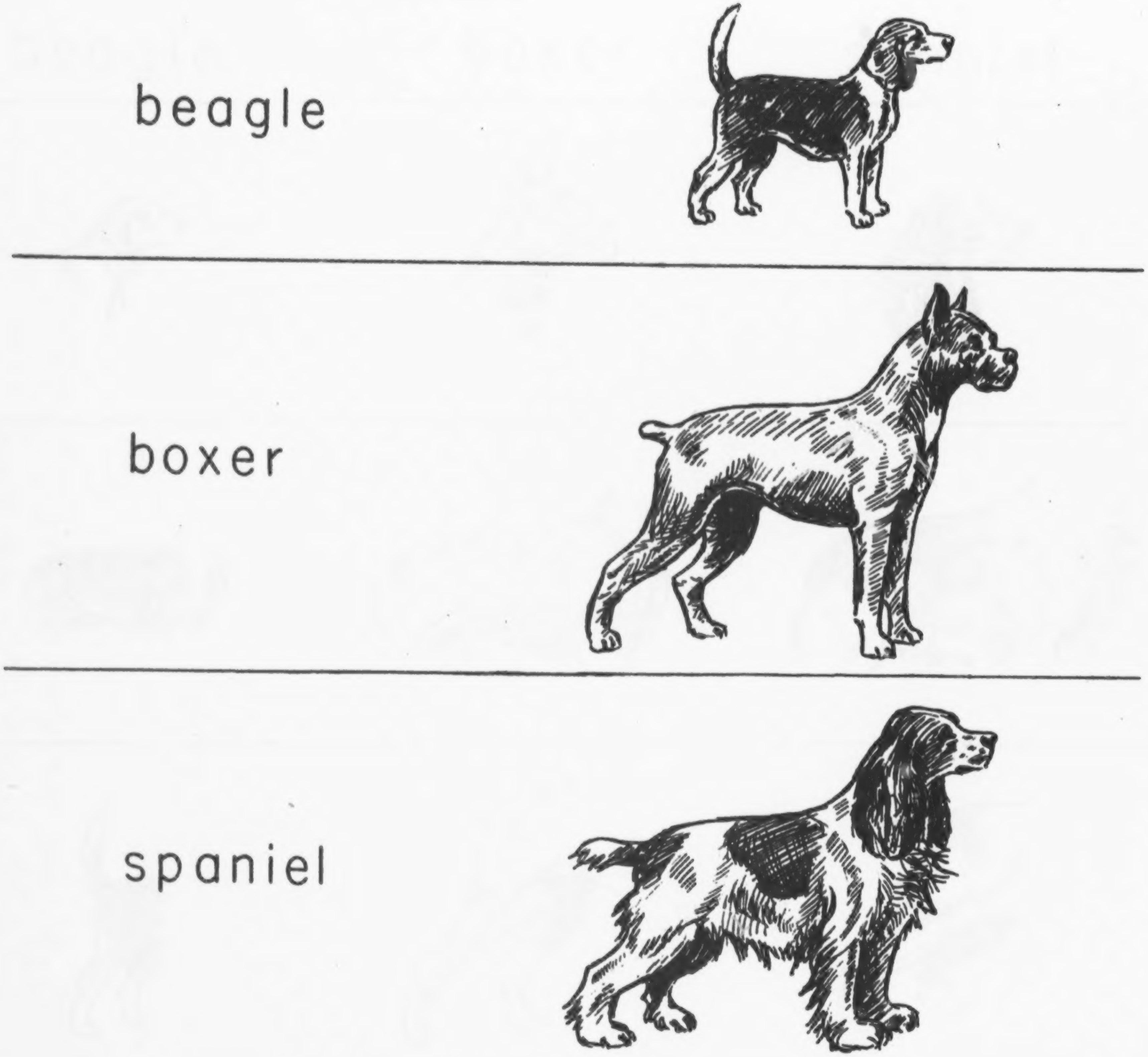
beagle
boxer
spaniel

Figure I. Object component method of presentation

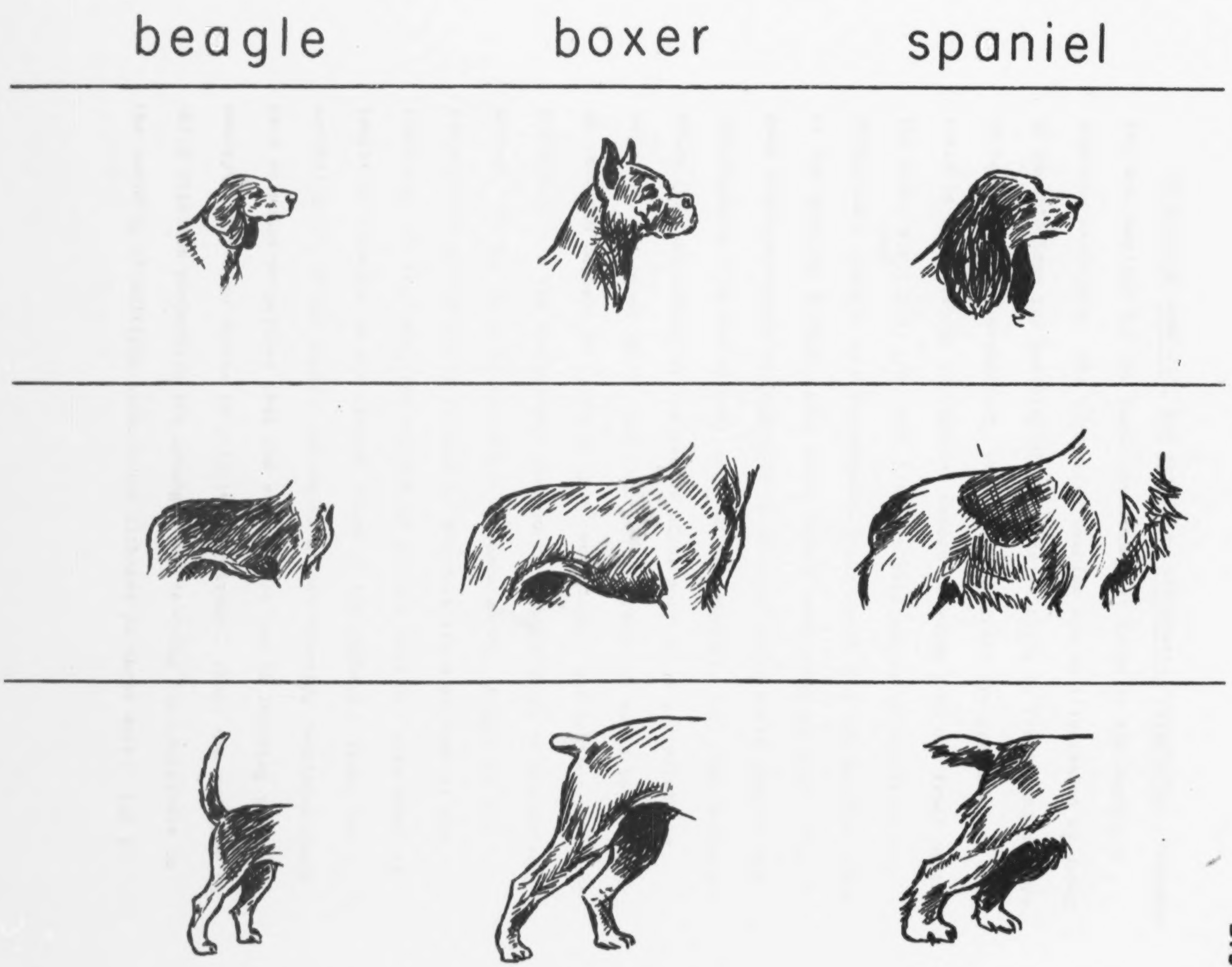
beagle
boxer
spaniel

Figure 2. Class-descriptive method of presentation

Sequencing specific, but multiple, associative structures. Sequencing and sampling are two basic problems that arise in the design of learning materials. The sequencing problem can be illustrated by using an example from the teaching of concepts relating to fractional numbers. In one concept of sequencing, programed materials are presented so that there is a consistent incremental change in going from one fraction to the next, e.g., 1/2, 1/3, 1/4, 1/5. In this series of fractions the denominator changes in a progressive order based upon the natural order of the numbers; however, many other orders also could be used. The same fractions could be sequenced in an order which would obscure the relationship with the natural order of the numbers, e.g., the denominators (or numerators) of the series might vary in an unpredictable sequence. In other words, the same set of fractions could be arranged so that the concept of "greater than" was taught, but neither the numerators nor the denominator changed in a progressive or predictable manner. In the first illustrative sequence above, changes in the denominator are inversely related to the relative magnitude of the fraction. In this way, the concept of greater than or "less than" is taught in relation to the natural order of the numbers. Thus, the natural order of the numbers serves to elicit counting responses which have stimulus properties that the student can use in learning some new concepts that also relate to relative magnitude. Thus, the sequence in which stimulus properties are arranged for teaching can contribute to the building of multiple association linkages in three ways: (a) it can provide redundancy patterns and thereby class-descriptive cues; (b) it can provide asynchronous relationships that make features more salient and therefore more likely to be used as cues; or (c) it can elicit discriminative responses that could serve as cues or as elicitors of either overt or covert performance.

Sampling, on the other hand, provides a basis for generalization of responses to stimuli that are not included in the set used for instruction. Since the data suggest that the generalization gradient is typically bell-shaped, the more that the stimuli depart from those used in training, the less effective they are. This suggests that more generalization could occur from using, in training, a widely spaced sample along the continuum of intended generalization.

Many natural situations are constrained with respect to the conditions under which learning must be accomplished. When a child is to learn a set of verbal associations such as "a chair, a table, and a desk are furniture," not only are no redundancies involved but also there are no available dimensions along which stimulus generalization can take place. Usually these specific, but multiple, associative paradigms must be learned in both directions. When this occurs, the learning of the second direction is a special case of transfer of training which has been called "association reversal" (Stolurow, 1956). Whenever association reversal occurs, it is necessary to decide whether the students should be given, as their first task, the one-to-many associational paradigm or the many-to-one paradigm. Stolurow and Bergum

(1958) found that differences in the set of terms that serve as cue-stimuli and those that serve as responses can affect the rate at which specific, but multiple, association paradigms are learned. They found that the direction more readily learned was the one in which the more complex set of terms was in the stimulus position.

When the two sets of terms do not differ in any obvious way, the question that arises is whether the divergent (one-to-many) structure is equal, easier, or harder to learn than the convergent (many-to-one). If one were easier than another, it would suggest that, with other factors equal, there was a preferred sequence for association reversal; namely, either divergent-convergent or convergent-divergent. Determining whether there was a difference in the learning effects of these two sequences was the third problem studied in this project. Since there were no *a priori* factors which suggested that one structure was inherently easier to cope with than the other,this was examined as an empirical question.

Intra-item sequencing and vanishing. In addition to the problem of programing, the teacher is confronted with the problem of providing optimum individual practice for each student. One factor that can be manipulated by the teacher to cope with individual differences is the amount of practice required for learning particular associations. Another factor is intra-item sequencing, and a third is vanishing. The last two factors provide additional dimensions of variation in teaching that could contribute to the adaptiveness of an instructional program to individual student needs.

Intra-item sequencing refers to the sequencing in which the eliciting stimulus function is provided in relation to the learner's response. For example, if the statistics student must learn to say "ogive" when shown a cumulative frequency distribution, then showing him the printed word next to a graph of a cumulative frequency distribution will provide an eliciting function and the student will say (or write) the word "ogive". If, on the other hand, the word "ogive" is withheld until the student has made a response to the graph, then the same physical event serves another function, namely, to confirm the correct response. Thus the stimulus that is attached to the correct response can be presented either before or after the response to the cue stimulus, and in each case it serves a different function. When it appears before the response the intra-item sequence can be called a prompting procedure. When it appears after the response the intra-item sequence can be called a confirmation procedure. The pedagogical problem studied in this project is one of determining which of these procedures should be used to achieve efficient learning.

Prompting and confirmation procedures differ in the intra-item sequence of the stimuli; this difference can be related to the basic process of contiguity. With practice, a learned response to a cue tends to be made sooner, so that the interval between cue and response becomes smaller and smaller, unless something prevents this from taking place. It can be argued that prompting procedure has an initial advantage in minimizing contiguity; but that, with a high degree of overlearning, confirmation has the advantage since there is no stimulus interposed between the cue and response. This argument was tested under different conditions of overlearning to see if a lower level of overlearning would produce a difference in favor of prompting and a higher level would produce one in favor of confirmation. The difference in the effects of these two intra-item sequences presumably would be revealed under the higher degree of overlearning. This was assumed to be the case since a high degree of practice would be required to reduce response latency to the point where the eliciting stimulus would become an interfering, or delaying, event. Thus, the hypothesis tested was that, although an elicitor would facilitate acquisition initially, it would interfere with the attainment of higher levels of association by preventing the minimization of the cue-response interval.

Operationally, *vanishing* can be defined in several alternative ways. One of these is in terms of the initial use of prompting and the later use of confirmation with the same materials. For example, if the orthographic forms of picturable nouns were being taught as cues in sight vocabulary training and if pictures were used as eliciting stimuli, then the printed word would serve as the cue in both the prompting and confirmation sequences. The pictures, however, would serve as either an eliciting stimulus or a confirming stimulus. Which of these two functions was being performed by a particular picture would depend upon whether the picture preceded or followed the learner's response. If the word "dog" was being taught, then a picture known to elicit the vocal response "dog" could be used in combination with the printed word so that an association between the printed word and the vocal response would be developed. In accomplishing this, it would be possible to begin with the prompting procedure, in which case the picture would either accompany the cue stimulus (printed word) or would follow it immediately. In either case, the picture would precede the learner's response to the word. Later, however, the confirmation procedure might be used with it; the picture would follow the learner's response; it would function as a confirmation stimulus and, therefore, as a type of reinforcement.

PURPOSE

The purpose of this project was to determine whether these concepts, derived from the author's theoretical position, could be translated into a set of operations that had useful implications for programing materials to teach the educable mentally retarded. This position formulates the problems of learning in stimulus terms which has the advantage of ready translation into operations performed upon instructional materials.

Chapter 3

GROUPING AND SPACING OF FRAMES WITH COMMON STIMULUS ELEMENTS–RECOGNITION AND RECALL UNDER STIMULUS CONTROL[1]

PROBLEM

Purpose of Study

This study compared the relative effectiveness of two frame sequences of an instructional program dealing with fractions concepts. The two sequences differed only with respect to the sequence in which a single set of frames was organized. One was structured so that it had a different set of frame-to-frame changes than the other had. A frame-to-frame change is any difference in the elements of adjacent frames when they are compared with each other. There may be one or more differences in the characteristics of two adjacent frames. In all other respects, the two sequences were alike. Their relative effectiveness was measured in terms of performance on tests of learning, retention, and transfer, as well as in terms of patterns of correlations obtained between both specific aptitudes and general ability test scores of the students and their scores on achievement, retention and transfer tests taken after they completed the program. The objective of the study was to determine whether recognition and recall could be placed under stimulus control.

Relevant Studies and Hypotheses

Two major hypotheses grounded in previous work provided the basis for this study. One was that different patterns of correlations between the students' achievement test scores and their ability and aptitude measures would be found following the two different learning experiences. The other was that any mean difference in achievement test scores would result from this difference between the two programs where the difference consisted of a greater number of frame-to-frame changes in one program.

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[1] This chapter is based upon a study conducted by G. P. Cartwright in 1962.

Stimulus control and asynchrony. Detambel and Stolurow (1956) obtained findings which suggested that the amount of change (asynchrony) in the critical cue stimulus elements of adjacent frames would be related to rate of learning, and that the sequence more effective for learning would result in an ordering of Ss with respect to achievement that would not correlate with their scores on a general ability test. More specifically, the sequence that was more effective for learning was found to be particularly beneficial for the lower ability groups so that their performance was indistinguishable from the high ability Ss. The same result is anticipated in the present study. The findings of Stolurow (1956) and Wulff and Stolurow (1957) suggest that the transfer effects from training with different sequences might be greater if asynchrony were produced by stimulus controls that took into account class-descriptive features of the stimulus materials.

Class-descriptive features of complex stimulus materials are the features which some, but not all, of the members of the stimulus set have in common. Thus, if two or more, but not all, stimuli are round and they are dissimilar in all other respects, then roundness is a class-descriptive feature of this set of stimuli. This concept has rather direct operational implications for the development of frame sequences in a self-instructional program. The first operation is to minimize the number of changes in critical cue characteristics of adjacent frames that relate to a subset of the total program formed by considering the concepts or terms being taught. The second is to maximize the amount of change between subsets of frames that are adjacent to one another in a program. The latter operation creates segmental units that are salient to the learner. These two principles of stimulus control provide conditions for the learner that facilitate the recognition of the cues presented by the reappearance of redundancies or stimulus sequence patterns in later frames. The particular patterns that are formed by the sequence in which the frames are ordered determines the specific features of the set of available features that are salient to the learner. The class-descriptive cues actually operative depend upon the grouping used. The salience produced in this way increases the liklihood that the features used for grouping will become the functional cues in learning. Features which are used to develop each subset are more likely to become the functional cues in learning than the other available features that would otherwise compete. Different numbers of features can be made salient by the way in which the two principles of stimulus control are applied to a set of materials. This, of course, is qualified by the inherent possibilities within the set of stimulus features for the particular materials involved.

Minor hypotheses following from stimulus control and asynchrony. One minor hypothesis is that the more features that are critical as cues for learning which are made salient to the learner, the more effective the training will be with respect to its transfer effects. Since the application of these principles to a particular set of materials can lead to different numbers of subsets, depending upon the particular stimulus features used, a second minor hypothesis is required to produce optimum arrangements.

This hypothesis is that the number of subsets will be related to learning, retention and transfer. Stolurow (1956) found that there were significant differences between groups who were given materials organized into three subsets as opposed to those who were presented with the same material organized into four subsets. The two subsets were equally logical subdivisions of the material using different class descriptive features as a basis for applying that principle. When random arrangements were used to provide groupings of three and four, respectively, the grouping factor itself did not produce significant differences. The trend may be suggestive, however, since with the random arrangements the four grouping was better than the three grouping; but when class-descriptive cues were operating, the reverse was the case with respect to mean number of correctly recalled values. These data suggest that the number of groupings produced may be somewhat less important than the particular stimulus features which are made salient by the grouping that is used.

Table 1 contains sequences which illustrate the independent variable in the present study. It is the frame sequence when certain factors are controlled such as the frames themselves and the concepts being taught. Sequence 1, in Table 1, could be described as a "grouped" sequence, whereas Sequence 2 could be a "distributed" sequence, as these terms are used here. Of the examples given for Sequence 1 of Table 1, there are two subsets which are determined by a definition of the concepts being taught. First, the concept of equality is taught and then the concept of inequality (less than). Within each of these subsets, the natural order of the numbers is preserved with respect to the denominator of the first fraction. In Sequence 2 there are six subsets in

Table 1

Illustration of Principles of Stimulus Control: The Class-Descriptive Cue Principle at Two Levels of Asynchrony

Frame no.	Sequence 1, grouped				Sequence 2, distributed			
	(1) Concept code	(2) Code of CC	(3) # of changes in CC	(4) Cue char's. (CC)	(5) Concept code	(6) Code of CC	(7) # of changes in CC	(8) Cue char's. (CC)
1	1 (=)	A = B		1/2 = 2/4	1 (=)	A = B		1/2 = 2/4
2		A = C	1	1/2 = 3/6		A = C	1	1/2 = 3/6
3		D = E	2	1/3 = 2/6	2 (<)	G < B	3	1/4 < 2/4
4		D = F	1	1/3 = 3/9		G < C	1	1/4 < 3/6
5		G = H	2	1/4 = 2/8	1 (=)	D = E	3	1/3 = 2/6
6		G = I	1	1/4 = 3/12		D = F	1	1/3 = 3/9
7	2 (<)	G < B	2	1/4 < 2/4	2 (<)	A < J	3	1/2 < 2/3
8		G < C	1	1/4 < 3/6		A < K	1	1/2 < 3/4
9		D < B	2	1/3 < 2/4	1 (=)	G = H	3	1/4 = 2/8
10		D < C	1	1/3 < 3/6		G = I	1	1/4 = 3/12
11		A < J	2	1/2 < 2/3	2 (<)	D < B	3	1/3 < 2/4
12		A < K	1	1/2 < 3/4		D < C	1	1/3 < 3/6
Amt. of change (asynchrony)			16				21	

terms of the concepts being taught, since the concept of equality is presented in pairs of frames separated by pairs presenting the inequality (less than). These subsets were formed by maximizing the amount of change from one to the other while minimizing the change within the subset. In doing this, the natural order of the numbers was not maintained with respect to the denominators of the first fraction. In this sequence, however, the amount of change between subsets of frames is maximized and the number of subsets is greater than in the first sequence. Thus, Sequence 2 generates more salient features than Sequence 1.

Assuming that the two principles of stimulus control provide conditions for the learner that facilitate the recognition of those cues which are used to produce redundancies or patterns, the particular patterns that are formed by the sequences in which the frames are ordered determines the specific features of the set of available cues that are salient to the learner. The salience produced in this way is assumed to increase the liklihood that these particular features will become the actual functional cues in learning. Features which are used to develop each subset are more likely to become the functional cues in learning than the other available competing cues. The natural order of the numbers is used to sequence the denominators of the initial fraction, the student's attention is thereby attracted to this stimulus feature which, coupled with the class cue utilized to organize the total subset, the class cues were the equal (=) sign which specified the relationship of equality and the sign for less than (<) in the case of the last six items.

Examination of the frame sequences in Table 1, in terms of the changes in cue characteristics (asynchrony) reveals that with Sequence 1 there is a total of 16 changes, whereas with Sequence 2 the total is 21. The minimum number of changes in a sequence of 12 frames with 3 critical cue characteristics (c) would be 11 (N-1 where N is the number of frames). The maximum number of changes that could be produced with 12 frames is 33, the formula for which is c(N-1) or 3(N-1). These three illustrative sequences are neither the minimum nor the maximum simply because factors other than the degree of asynchrony were taken into account; namely, the natural order of the numbers and the concept being taught. In Sequence 1 the denominators increased progressively from 1/2 to 1/3 to 1/4 and then decreased from 1/4 to 1/3 to 1/2. Also, within the first set, the concept of equality is common to the six frames; and, in the second set, the concept that is common to the first six frames is "less than". If pairs of frames had not been formed by placing together two that contained the same initial term, for example, then the amount of change which would have been possible would have been greater than for the set represented here. Thus, by constraining the sequence through the use of two principles of stimulus control; namely, minimum total asynchrony and class-descriptive cues (minimum asynchrony within subsets but maximum between subsets), a program was generated that resulted in approximately 48% change rather than the minimum amount which would have been 33% in this example involving three cue characteristics. Assuming that there were two frames per page and that a second sequence was to be generated by simply rearranging the pages, then Sequence 2 would be one possibility that would increase the amount of asynchrony so that it approached the maximum value within the constraints described. In this example, it resulted in approximately 64% of the maximum amount of asynchrony.

A subdivision of the second minor hypothesis relating to program sequences investigated in the present research was that with frames organized in the manner of Sequence 1 (Table 1) the student would be attracted more to the stimulus features that varied within the two subsets than he would to the features representing the class-descriptive cues (equality and less than). To the extent he did, the pattern of change within the fractions would be more salient than other characteristics of the stimulus materials. Presumably, this particular pattern would provide him with a useful mnemonic so that he would be able to remember better the materials taught than he would if there were more changes taking place within the sequence.

Another subdivision of the second minor hypothesis was that the arrangement of frames, such as that represented by Sequence 2 (Table 1), would make more characteristics of the stimulus material salient to the learner and, thereby, promote greater transfer to new tasks in which all features had to be taken into account for correct performance.

Working hypotheses. The working hypotheses were: (a) that different learning test performances would result from the two sequences; (b) that different retention test performance would result from the two sequences; (c) that different amounts of transfer effect would result from the two sequences; and (d) that different aptitudes would be related to performance under each of the two sequences.

METHOD

Subjects

Forty educable mentally handicapped children in the Division of Special Services, Evanston Township High School, Evanston, Illinois were used as subjects in this study. The students were assigned randomly to one of two groups of 20 students each (Table 2). Four students were dropped because of absences and missing data, leaving 20 in the group using Sequence 1 and 16 in the group using Sequence 2.

Table 3 summarizes the S's records maintained by the high school. Intelligence test scores were missing for three boys, so that the group mean was substituted for the missing data. The California Achievement Test (1957 edition-Form W) was administered as part of the regular school testing program in April, 1961.

Procedure

Testing. On the two days preceding the introductory material, each student took a 64-item test (test I) to determine his knowledge of fractions. Immediately upon completion of the programed material, each child took the test again (test II) to provide both a pre- and a post-test score.

A third test (test III, consisting of parts A and B) was administered to each child approximately 21 days after the completion of the programed material. One-half of the test (part A) was designed to test for transfer effects. It contained items not included in the program but similar in general format. The other half of the test (part B) was used to measure retention.

Table 2

Distribution of Students Among Classes

	Program		
	Sequence 1	Sequence 2[a]	Total
Freshmen	8	6	14**
Sophomores	4	6	10
Juniors	3	4	7
Seniors	5	4	9
Total	20	20	40

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[a] Three freshmen and one senior in Sequence 2 did not complete the program which left 16 for the final analysis.

Table 3

Means and Standard Deviations of Student Characteristics for Both Groups

No.	Student characteristics Description	Group Means and Standard Deviations Sequence 1, grouped (N = 20) $\overline{X}$	 Sequence 1, grouped (N = 20) S.D.	 Sequence 2, distributed (N = 16) $\overline{X}$	 Sequence 2, distributed (N = 16) S.D.
1	CA (in months)	205.95	17.23	203.62	15.53
2	MA (in months)	145.95	20.12	148.44	16.66
3[a]	WISC Verbal MA (V)	150.55	24.64	149.44	17.94
4	WISC Performance MA (P)	150.25	22.89	156.69	23.66
5	WISC Full Scale MA (FS MA)	145.65	20.47	148.19	16.74
6[b]	CAT Reading Vocabulary (RV)	5.22	1.50	5.54	1.41
7	CAT Reading Comprehension (RC)	5.31	1.69	5.47	1.23
8	CAT Total Reading (T R)	5.29	1.52	5.53	1.17
9	CAT Arithmetic Reasoning (AR)	5.60	1.50	6.01	1.47
10	CAT Arithmetic Fundamentals (AF)	5.82	1.16	6.27	1.43
11	CAT Total Arithmetic (T A)	5.74	1.26	6.16	1.40
12	CAT Total Language (T L)	5.46	1.76	5.61	1.06
13	CAT Total Battery Grade Placement (TB GP)	5.51	1.46	5.76	1.11

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[a] WISC = Wechsler Intelligence Scale for Children

[b] CAT = California Achievement Test

Learning. On the first day of the study, the teaching machines and programed materials were introduced. As each student entered the room, he was instructed to go to the machine bearing his name. The teacher tried to motivate the students and to interest them in the machines and the learning task. The students were told that the machines were constructed especially for their class and that a report of the results of the study would be made to the University of Illinois and to Washington, D. C.

The entire period (approximately 50 minutes) of the first day the class worked step by step through several pages of material designed to teach them to operate the machine and to teach them the meanings of abbreviations used in the program in order to help cue their responses. For example, the abbreviations "wd" or the sign "#" was used preceding an answer space to indicate to them that a word, or a number, respectively, was required as a response. Individual help was given to students who had difficulty understanding the procedure.

On the second day, a brief review of the procedure was given; and the students began working on the first roll of the program material. Most of the questions asked during the first two days concerned words that had been presented on the first day but were not remembered by the students, e.g., divide, equal, wrapper.

The procedure for the remainder of the study was routine in nature and consisted primarily of changing rolls of material in the machines as needed. Few questions were asked, and few discipline problems arose. The materials were placed in the machines in advance of each class; and the students, for the most part, went directly to work upon entering the room without waiting for a bell to indicate the resumption of class. At the end of the period, each student wrote his name on his material and went on to his next class.

Materials

Program. There were nine sections in the program. The first dealt with equality of fractional parts of an object and with the concept that when a figure is divided into n equal parts, one of the n equal parts is 1/n of the whole figure. The frames in this section contained figures representing concrete objects, such as candy bars, boxes, cakes, sticks of butter, etc. Section 2 repeated the concept but used drawings of abstract figures instead of real objects. Section 3 dealt with linear measurement rather than with the division of familiar objects and the unit selected was the inch. The emphasis was upon discrimination training. Therefore, if the division of measurement treated in a frame was eighths, its relationship with halves was illustrated by showing the inch divided into both halves and eighths. Similarly, the relationship between fourths and eighths of an inch might be shown in a drawing accompanying a frame. Section 4 introduced the words numerator, denominator and their definitions. In Sections 5 and 6, two circles were shown for each item. They were both the same size but divided differently. For example, in the first item of Section 5, one circle was divided into two equal parts and the other into three equal parts. The item compared 1/2 with 1/3 to show that 1/2 is larger than 1/3. The next item compared 1/2 with 1/4 and the program continued in this manner through the comparison of 1/2 and 1/10. The next series of frames dealt with 1/3 compared with 1/4 and then with 1/5, and so on. This pattern was repeated through the comparison of 1/9 and 1/10. All of the comparisons involved fractions with a numerator equal to 1. Section 7 was similar to Sections 5 and 6 but used drawings of cards instead of circles. Section 8 contained frames dealing with the concept n/n = 1. Section 9 dealt with the relationships of inequalities and of equalities illustrated by a rectangle divided into proportional segments. The upper half of the rectangle, for example, might be divided into three equal parts with the numeral 1/3 appearing within each part. The lower half of the rectangle might be divided into six equal parts, with each part showing the numeral 1/6. The student could readily see that the one-third section was greater than the one-sixth section and that the section labeled 1/3 was equal to two of the sections labeled 1/6.

The program, titled An Introduction to Fractions, was based upon one previously written and used by Smith (1962), who employed it with normal children and in a cutback-page format (see Stolurow, 1961). The content of the program was based upon Making Sure of Arithmetic, published by Silver Burdett and typically used as a fifth-grade arithmetic textbook.. Pages 167 to 180 of this text were used in developing the program. The program used by Smith was revised for the present study by (a) lowering the readability level[2] and (b) expanding the program to fill in logical gaps of fractions and integers and in the sequence of fractions. Table 4 is a resumé of the program.

Three to six program frames were mimeographed on each legal-size page of paper. Each page contained a drawing which referred to the concept to be learned. With a few exceptions, each page was independent of the other pages in that it contained a set of steps designed to teach one or more units of the program, e.g., that the numeral 1/2 stands for one of two equal parts.

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[2] Inspection of achievement levels of the mentally retarded adolescents used in this study showed that their mean reading grade placement was 4.7. The four lowest grade placements were 2.8, 3.0, and 3.7.

In every case, all of the steps relating to one unit were on a single page, although some pages contained steps relating to more than one unit.

Table 4 summarizes the contents of the program in terms of the concepts, fractions and vehicles used. The so-called vehicles are the drawings of objects employed to represent various fractional components of familiar volumes.

Independent Variables

Program variable. In preparing the two sequences which were the independent variable, none of the frames on a page was changed; rather, the sequence of pages was altered, while asynchrony was kept constant. In other words, the difference between Sequence 1 and Sequence 2 was in the pattern of the fractions from frame to frame.

With Sequence 1 the fractions were arranged so that the denominator progressively increased, e. g., from 1/2 to 1/3 to 1/4, while the numerator remained constant. Then the reverse was true: the denominator was held constant while the numerator was changed progressively. The materials making up Sequence 2 were prepared so that the pattern of the numerals would not be as apparent as in Sequence 1. Thus, the variable in this study was the rule for determining the pattern of the quantities represented in the frames. It was to change progressively the values of the denominator and then of the numerator. This rule was used for two reasons. One was to make the denominator and numerator salient to the learner so they would function as class-descriptive cues. The second reason was to provide students with an opportunity to use their prior learning of the natural order of numbers. Presumably those who had learned this were able to recognize the patterns represented in the

Table 4

Resumé of Fractions Program

I. **Concepts**

A. **Definitions**

1. **Fractions**
   - numerator
   - denominator
   - a/n is read a n'ths

2. **Object divided into parts**
   - a of n parts

3. **Multiplication**

4. **Equality**

B. **Equality - Inequality**

1. $\frac{n}{n} = 1$ or $1 = \frac{n}{n}$

2. $1 > \frac{n-1}{n} > \ldots > \frac{1}{n}$

   or

   $\frac{1}{n} < \frac{2}{n} \ldots < \frac{n-1}{n} < 1$

B. **Cont'd.**

3. $\frac{a}{n} > \frac{a}{n + x}$

   or

   $\frac{a}{n + x} < \frac{a}{n}$

4. **More than - less than**

5. **Transitivity: if a = b and b = c, then a = c**

C. **Operations**

1. **Reduction of Fractions**

II. **Objects**

A. **Real Objects**

1. **Candy bar**
2. **Dish**
3. **Stick of butter**
4. **Wrapper from stick of butter**
5. **Card(s)**
6. **Ruler**
7. **Cake**

B. **Geometric Forms**

1. **Circle(s)**
2. **Rectangle**

C. **Fractional Numerals**

D. **Fractional Numerals in Matrix**

III. **Fractions**

1/2, 2/2
1/3, 2/3, 3/3
1/4, 2/4, 3/4, 4/4
1/2, 2/5, 3/5, 4/5, 5/5
1/6, 2/6, 3/6, 4/6, 5/6, 6/6
1/7, 4/7, 6/7, 7/7
1/8, 2/8, 3/8, 4/8, 5/8, 6/8, 7/8, 8/8
1/9, 3/9, 5/9, 8/9, 9/9
1/10, 2/10, 4/10, 5/10, 6/10, 8/10, 9/10, 10/10
1/12, 2/12, 3/12, 4/12, 6/12, 7/12, 8/12, 9/12, 10/12, 12/12

stimulus and in the response so as to establish the concept of a reciprocal relationship between the increasing numerical value of the denominator and the decreasing proportion of the total which the fraction represents.

The independent variable was different frame sequences; it was produced by applying two different rules for sequencing a single set of frames. One rule used the class-descriptive cues (Stolurow, 1956) of denominator and numerator, each of which was made salient by progressively changing the value of one of them from frame to frame. The program generated by this rule was referred to as the grouped arrangement of frames and it was designated Sequence 1. It was presumed to provide the learner with a set of class cues that he could readily associate with counting, which, in turn, would provide him with response-produced cues. These could mediate relational responses such as "less than" or "greater than". The ability to generate the numerical progressions should aid the retention of the responses taught by the program.

A second sequence was prepared by interchanging the pages of the original sequence. In this way the pattern represented by the progressive changes in value of the denominator and numerator was destroyed and thereby made non-functional during learning. In Sequence 2 the frames were sequenced so that they did not fall into a consistent pattern; this presumably made it likely that several other features would become salient to the learner. Each learner could then use any one of a variety of stimulus features as cues. It is possible that the saliency of a greater number of stimulus features would provide the learner with an advantage when he was required to use what he had learned. This should be particularly true when the new materials to which he was asked to respond were simply new combinations of familiar elements, ones that had been used in the instructional program but in different combinations. For the reasons given, Sequence 1 was assumed to aid retention more than transfer whereas Sequence 2 was assumed to aid transfer more than retention.

Subject variables. The subject variables in Table 3 are as follows: Chronological Age (CA); Mental Age (MA): Wechsler Intelligence Scale for Children (WISC), Verbal MA (V), Performance MA (P), Full Scale MA (FS MA).

Form W (1959) of the California Achievement Test (CAT) was administered early in April, 1961 and the following scores were obtained: Reading Vocabulary (RV), Reading Comprehension (RC), Total Reading (T R), Arithmetic Reasoning (AR), Arithmetic Fundamentals (AF), Total Arithmetic (T A), Total Language (T L), Total Battery Grade Placement (TB GP).

Each of these variables was correlated with the dependent variables obtained from performance test.

Dependent Variables

The dependent variables used to compare the effectiveness of the two sequences were obtained from an objective test consisting of two parts: (a) the material covered by the program -- "identical" subtest, and (b) closely related, but different in the combinations of stimulus elements -- "different" subtest. The former set of questions consisted of the terminal frames taken from the program. The latter set were comparable to the first in format and in all other respects except that the numerals used were not those employed in the instructional program. Consequently, these items constituted a sub-test which will be referred to as a transfer test. They were called the "different" items to differentiate them from the set of terminal frames used as test items to measure learning and retention. These were called the "identical" items.

The test format was comparable to the program format except that in the test no feedback was given the students. By using the same format for the pre-test the students received practice in working with new materials under conditions which were almost identical to those that obtained during their subsequent learning experience. Presumably, this minimized errors due to the novelty of the format and the machine, etc. In this way the content of the frames became the critical stimulus associated with their performance.

The same test was used as a pre-test, an immediate post-test and a re-test. The test was administered 21 days after learning and is referred to in Table 5 as the re-test with the two sub-tests separately scored -- "different" and "identical".

Three types of scores were obtained from the test: (a) raw scores; (b) per cent of maximum possible gain scores, and (c) residual scores. Raw scores were simply the number of correct responses. The per cent maximum possible gain score was obtained as follows: first, the pre-test score was subtracted from the maximum possible score to obtain the denominator of a fraction, the numerator of which was the difference between the pre-test score and the post-test score. This latter score is called the gain score and the percentage which it represents of the maximum possible gain identified the per cent of maximum possible gain for individual students.

Table 5

Means and Standard Deviations of Raw Scores and Residual Learning Scores for Both Groups

Tests			Group means and standard deviations			
			Sequence 1 - grouped (N=20)		Sequence 2 - distributed (N=16)	
Type	Questions	Scores	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Pre-test		Raw	30.90	13.66	26.12	10.64
Post-test		Raw	47.85[a]	10.94	45.25[a]	10.80
Pre- post- test	Total	% maximum gain	55.65	29.15	50.75	23.18
Re-test	Different	Raw	25.90	8.29	27.00	5.78
Re-test	Identical	Raw	25.25[b]	8.62	21.06[b]	9.92
Pre- post- test		Residual	.02	7.75	-.02	9.74
Pre- re- test	Different	Residual	1.14	7.10	-1.42	4.94
Pre- re- test	Identical	Residual	-.86	6.69	1.08	8.42

[a] Difference between pre- and post- test means are significant at the .05 level for both groups.

[b] Difference between Group 1 re-test (identical questions) and Group 2 re-test means are significant at the .10 level.

The regression score was obtained by correlating the pre-test with the post-test score or with the re-test score and then computing the regression equation. This equation was used to determine the predicted score for each student and his predicted score was subtracted from his actual score to obtain an algebraic difference score, which is called the regression score (DuBois, 1962).

RESULTS

Comparability of groups.

Reference to Table 3 indicates that the two groups were comparable to one another in terms of their chronological, mental age, and aptitude scores.

Achievement scores.

The means and standard deviations of the raw scores and the per cent maximum gain scores and residual scores are summarized in Table 5. Comparisons of these means indicate that the post-test raw scores for the two groups were significantly different at the .05 level. They also indicate that the re-test scores for the two sequences were significantly different at the .01 level for the sub-test covering "identical" items (terminal frames). These data suggest that the grouping of frames according to class-descriptive principles results in a higher learning score and a higher retention score than does the distributed arrangement of materials. This finding confirms one of the hypotheses of the study. However, the result relating to the sub-test scores dealing with the "different" items, while showing a trend in the right direction, is not a significant effect. The raw sub-test score mean based on the "different" items is higher for the distributed condition at the time of re-test. The residual score mean for the "different" items based upon the correlation between the pre- and re-test shows an average negative deviation of the actual value from the expected value. The residual score mean obtained from the students who received the grouped arrangement (Sequence 1) showed an average positive deviation of actual scores from the expected values. The reverse was true for the items comprising the "identical" sub-test.

The residual score mean obtained from the students who received the distributed arrangement (Sequence 2) showed that the reverse trend; namely, a negative mean deviation of residual scores for the "different" sub-test items and a positive mean deviation for the "identical" sub-test items.

Table 6 summarizes the matrix of intercorrelations among student characteristics and the various achievement test scores. There are two general findings here. The first indicates a relatively high intercorrelation among the student characteristics as noted by the number that reached significance beyond the .05 level. This suggests that relatively few independent characteristics or factors are present in this group of scores. The second findings is of greater significance for the present study. It is the difference between the correlations relating identical pairs of variables under the two different sequences of frames. For example, the correlation between chronological age and the pre- post- test percentage-of-maximum-possible-gain score was -.17 for the students who received Sequence 1 and +.27 for those who received Sequence 2. This suggests a very different patter of relationship between chronological age and this dependent variable which measures learning. Still other correlations that are significantly different for the two frame sequences are summarized in Table 7. These other relationships between a characteristic of the

Table 6

Intercorrelations Among Student Characteristics and Residual Learning Scores for Both Groups
(Group S-1 Grouped Condition in Upper Triangular Matrix[c]; Group S-2
Distributed Condition in Lower Triangular Matrix[d])

Variables	Student characteristics													Achievement test			
	CA	MA	WISC[a]			CAT[b]								Scores			
						Reading			Arithmetic			Lang.	TB				
			V	P	FS IQ	RV	RC	T R	AR	AF	T A	T L	GP	Pre-post % max. gain	Pre-post res.	Pre-re res. diff.	Pre-re res. ident.
CA		64**	58**	51*	63**	47*	50*	50*	32	38	36	61**	53*	-17	34	07	04
WISC																	
MA	85**		83**	75**	100**	53*	53*	56*	58**	61**	63**	60**	63**	-01	18	-20	-17
V	79**	75**		28	84**	68**	57**	64**	58**	53*	59**	61**	66**	19	02	-30	-26
P	63**	84**	30		75**	14	27	22	34	46*	41	36	34	-23	26	04	08
FS IQ	86**	100**	75**	84**		52*	53*	55*	58**	61**	63**	60**	63**	-00	17	-20	-15
CAT																	
RV	40	42	48*	19	42		83**	95**	77**	52*	69**	80**	86**	28	-08	-46*	-32
RC	30	40	43	20	40	58*		96**	83**	68**	79**	91**	95**	34	-05	-30	-13
T R	40	47*	51*	22	47*	90**	87**		84**	64**	78**	90**	95**	32	-07	-39	-22
AR	36	37	56*	08	36	78**	59**	78**		82**	96**	80**	92**	53*	-30	-19	03
AF	25	11	45	-17	12	72**	40	64**	88**		94**	67**	79**	45*	-25	-16	-08
T A	32	26	52*	-04	26	78**	52*	74**	97**	97**		77**	90**	51*	-29	-20	-03
T L	49*	56*	54*	34	56*	76**	67**	82**	76**	82**	72**		96**	23	12	-20	01
TB GP	44	45	58*	16	45	89**	74**	92**	92**	84**	91**	90**		38	-07	-27	-07
Pre-post-% max. gain	27	51*	28	49*	51*	26	23	29	45	18	33	56*	40		-81**	14	04
Pre-post-res.	-33	-49*	-26	-50*	-49*	-29	-22	-30	-41	-18	-31	-54*	-39	-96**		-18	02
Pre-re-res. diff.	04	-03	02	01	-02	-14	-10	-14	-22	04	-09	-09	-11	-18	14		61**
Pre-re-res. ident.	04	03	-04	14	04	-37	-41	-44	-40	-24	-34	-31	-38	-00	-06	74**	

[a] WISC = Wechsler Intelligence Scale for Children.

[b] CAT = California Achievement Test.

[c] Sequence 1, grouped: N=20, r=.57 at the .01 level, r=.42 at the .05 level, two-tailed test.

[d] Sequence 2, distributed: N=16, r=.59 at the .01 level, r=.47 at the .05 level, two-tailed test.

* Significantly different from 0 at the .05 level.

** Significantly different from 0 at the .01 level.

Table 7

Correlations Which are Significantly Different for the Two Sequences

Independent variables	Dependent Variables			
	Sequence 1		Sequence 2	
	Pre- post- % max. gain (1)	Pre- post- residual (2)	Pre- post- % max. gain (3)	Pre- post- residual (4)
CA	-17	34	27	-33
WISC				
MA	-01	18	51*	-49
V	19	02	28	-26
P	-23	26	49*	-50*
FS IQ	00	17	51*	-49*
CAT				
Total L	23	12	56*	-54*

*These correlational values are significantly different from zero at the .05 level.

[a] To be significant the algebraic difference in the corresponding r values in the odd columns should be .59 for the .01 level and .47 for the .05 level. The same is true for the corresponding values in the even columns.

subjects and a dependent variable, which were significantly different for each of the two sequences, are in corresponding rows of Table 7. The odd-numbered columns under the heading Sequence 1 and Sequence 2 are to be compared with each other. The even-numbered columns are to be compared with each other since they represent the corresponding pairs of values for the two sequences. It is noteworthy that with Sequence 1 (grouped) three of the independent variables correlated negatively with the pre- and post- percentage-of-maximum-possible-gain score, whereas the same variables correlated positively when students studied the same frames but in Sequence 2. A pattern is even more apparent when the dependent variable is the residual score. The correlations with this dependent (distributed) variable are summarized in the even-numbered columns of Table 7. All correlations with it are positive under Sequence 1 (grouped) and all corresponding correlations are negative in the case of Sequence 2 (distributed).

One of the more interesting findings is that the total language score showed a positive correlation of .12 with the pre- post- residual score under Sequence 1 and a negative correlation of .54which differed significantly from zero under Sequence 2. This suggests that changing the sequences imposed a task condition that related to the use of language skills by the learner. Presumably, the distributed arrangement of frames produced behaviors which tended to correlate negatively with verbal ability whereas the grouped arrangement of frames produced behaviors which tended to correlate positively with verbal ability.

SUMMARY

This study, using two groups of educable mentally retarded subjects, teen-agers with an average IQ of about 70, resulted in some interesting findings. The mean performance of the two groups trained with the same frames but in different sequences was significantly different upon completion of training. Also, several correlations between student characteristics and final achievement were significantly different for the two groups. The post-test raw scores indicated that both groups of students had made significant gains as a result of their respective learning experience. The group who received the sequence of frames that was organized in a grouped arrangement which revealed the inverse relationship between increments in the denominator and the decrements in the proportion of the total which the fraction represented, achieved higher retention scores than did the group for whom the sequence of the frames was not so organized. Examination of the correlations between student characteristics and measures of learning revealed that the independent variable of frame sequencing did result in significantly different correlations. These data suggest that simply changing the sequence of frames, other variables controlled, can result in a different learning task in that it makes different demands upon the requisite aptitudes for making comparable gains in learning. This is probably the most important finding of the study, since it suggests that for a contingency theory of learning the optimum sequence for a learner may be contingent upon his aptitudes or abilities. Therefore, the study suggested a line of research, namely, studies which would reveal the specific nature of the effects which variations in the organization of learning experiences have upon the learner. Research which mapped the correlations between student characteristics and learning scores could indicate the way in which materials might be organized so as to make maximum use of the particular aptitude and ability patterns of the learner. Data of this kind would permit a much higher degree of individualization of instruction that has been obtainable thus far. It would mean that educational prescriptions of a highly selective nature would be possible simply knowing the learner's aptitude scores. These could be accomplished with computer-based instruction

Chapter 4

THE EFFECTS OF SEQUENCE IN LEARNING COMPLEX ASSOCIATIVE PARADIGMS THAT ARE TAUGHT IN BOTH A FORWARD AND A BACKWARD DIRECTION

PROBLEM

Associative paradigms (or structures) can be defined as the patterns of associations that specify the cue and response relationships required for criterion performance on an associative task. For example, if S_1 is a cue term and R_1 is a response term, then learning to make the response symbolized by R_1, whenever S_1 is presented, represents a one-to-one associative paradigm. Learning to say "six," when shown 5 + 1, 4 + 2, and 3 + 3, is an example of many-to-one associative paradigms. Similarly, learning to respond correctly to the question, "What are the factors of 12?" is a one-to-many associative paradigm. Learning to give the possible causes of a set of symptoms is a many-to-many associative paradigm (Stolurow, Hodgson & Silva, 1956).

Many associative relationships are learned in both a forward and backward direction, e. g., French-English and English-French translations. This special case of transfer is called association reversal (Stolurow, et al., 1956). Simple associative chains, e. g., the alphabetic sequence, have an obvious polarity, for while it is easy to learn to recite the alphabet from A to Z, it does not follow that it also can be recited backward, even when it is overlearned in the forward direction. Each direction of association requires separate practice for its mastery, even though the same elements are involved.

Learning an associative paradigm, first in the forward and then in the backward direction, can be viewed as a special case of transfer of training. As such, a question arises concerning the symmetry of the transfer effects when the paradigms are not linear, as is the case with such specific, but multiple, associative paradigms as the products (forward direction) and factors (backward direction) in mathematics. It is possible that there is an asymmetrical relationship so that it is easier to learn both skills if one first learns to multiply and then to factor, rather than if one first learns to factor and then to multiply. This is the nature of the problem studied in this chapter. Underlying it are both structural and semantic factors, either or both of which could contribute to any asymmetry that might be found. The problem was studied in a preliminary way and only in the context of verbal concept learning. Mentally retarded children were given programed learning materials that were prepared by means of a programed instructional heuristic. Another aspect of the study is the method of developing self-instructional materials from a heuristic.

In the first application of the heuristic, a secretary generated both the frames of the program, in prose form, from a code prepared by the educational programer, and a lexicon which defined the code terms. In the second study, the heuristic was changed and rewritten so that a computer (instead of a secretary) generated the frames of the program used to teach the students. The prose form of the program was not written by an educational programer in either case.

This chapter presents methods used to automate the preparation of self-instructional materials for use in teaching concepts and spelling to EMH children. It also reports the results obtained from using these materials to teach by means of two programs in which different sequences of the same frames were used. In general terms, the programs dealt with a structural problem that relates to the teaching of concepts. In one program, the one-to-many direction of association was taught first; then it was reversed and the many-to-one direction was taught. This can be symbolized as the 1-M, M-1 program. The second program (many-to-one, then one-to-many) can be symbolized as the M-1, 1-M program. Since the same frames were used, there was control over the semantic factors.

Hypotheses

It was hypothesized that transfer effects (e.g., from M-1 to 1-M) from the two programs would not be comparable, even when the semantic elements within each M-set had essentially no associative significance for one another. In other words, the semantic elements (words) within each M-set were not orthographically related, nor were they known to elicit one another in free or controlled association.

The asymmetry hypothesis was based upon the assumption that an M-1 set, the paradigmatic structure of stimulus generalization, would be learned more rapidly than a 1-M set, the paradigmatic structure of response generalization. This was an intuitively-derived hypothesis, based upon neither a theory nor a set of existent data.

METHOD

Coding

One way to communicate to readers both the content and structure of an existing program is to code the content of the frames.[1] It seemed reasonable that the frames of a program could be coded prior to their actual writing; the code, then, could provide the educational programer with a set of "short-hand"specifications for frame composition, as well as for sequence. The advantage is that the educational programer would then have both the content and structure of the program in a convenient form since the code elements would be highly denotative. A proper code could give the educational programer more precise control over content and sequence than he has without one, since it is an efficient means of presenting information. It also is a convenience, for sequences can be readily scanned and, if desirable, changed by rearranging the code, rather than the actual frames. In addition, encoding beforehand reduces the semantic "noise" that often occurs in preparing frames of a program without specifying their characteristics in advance.

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[1] An example of frame coding, of the type currently under development in the Training Research Laboratory, University of Illinois, appears in L. M. Stolurow & Leone M. Smith. The Effectiveness of Two Different Sequences of Programed Elementary Mathematics. Urbana, Ill.: University of Illinois, Bureau of Educational Research, USOE Title VII, Contract 711151.01, Tech. Rep. No. 1, Sept., 1963.

Code elements. The first step in the process of coding is to specify the variables involved. More than one level is involved in doing this; for example, the sentence, "1 is _______(smaller, bigger) than 1/12,".as a frame from a program on fractions, can be analyzed into fixed and variable elements. Thus, a given sentence form can be analyzed in terms of the elements that are fixed and variable. The word is, the blank, the word than, and the period can be treated as fixed elements of a sentence form which can be used with a variety of content. The 1, the words smaller, bigger, and the fraction 1/12 are elements which could change from frame to frame. In this way, the content, but not the sentence form, could vary. A specified set of sentence forms also can serve as variables; and, for any one set, or any larger set of them, the words can vary. In this sense, the material to be learned can be considered as ordered sets of variable elements, first, as sentence forms and then as words and/or values within sentence forms which are to be associated with one another through their arrangement in the sentence form. In doing this, a complete program can be specified unambiguously by a code, for the code not only uniquely identifies the semantic elements but also their relationships, as represented by a particular sentence form.

Words and word relationships. The word sets used in preparing the programs used in the present research were chosen from materials described by Underwood and Richardson (1956). The choice of words for use in developing the program was made using a dual criterion: first, only words which were commonly known to children were chosen; and second, a grouping (set) of words was made up by combining words that would not be very likely to elicit each other according to association norms. For example, the presentation of the word "soft" might elicit several words such as "pillow" and "feather": but it would not be as apt to elicit the words "peach," "tongue," or "tomato," even though these things can be soft. Furthermore, the words "peach," "tongue," and "tomato" are most likely to elicit the response "to eat," which, therefore, was excluded from the set used.

Program Development: Pilot Study

In the first attempt to use a code procedure in preparing a program, a typist interpreted the code statements and composed frames from these codes. The educational programer then developed the program by writing the code statements and assembling them in the order in which they would be used. He also prepared a dictionary for the typist so that the words for use in the prose form of the program could be identified from the codes. In addition, he prepared a set of general instructions for the format. The actual program frames were first written by the typist in English, and then assembled by the typist in the code sequence when she made the stencils for the duplicating machine. The program was duplicated and used in Koncept-O-Graph teaching machines with separate answer tape attachments to record student responses.

Pilot study students. The program was tested at Lincoln State School[2] with 12 subjects whose characteristics are given in Table 1.

Pilot study observations. The recording of responses on the separate tape mounted in a box on the side of the Koncepto-O-Graph appeared, at first, to be the best way to collect the data. While the subjects were responding to the program, it became apparent that the unreliability of these machines would cause some trouble in the data analysis. In order for the data processor to relate a S's answer to the appropriate frame later on, the tape must move in synchronization with the program, but this was not always the case. It was not possible for the experimenter to keep up with the malfunctioning

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[2] The cooperation of Dr. Joseph Albaum and his staff at Lincoln State School, Lincoln, Illinois, is gratefully acknowledged.

Table 1

Pilot Study: Stanford Binet and ASAT Group Means

Measure	Mean	S.D.
CA	172.1[a]	13.3
Stanford-Binet		
MA (Binet)	122.8[a]	19.1
IQ (Binet)	71.6	8.4
ASAT[b]		
Sentence Reading	3.7	0.8
Paragraph Reading	3.2	1.0
Average	3.4	0.9

[a] These values are in months.

[b] This is the "American School Achievement Tests, part I, Reading." Young, R. V. and Pratt, W. E.: Public School Publishing Co.

of these machines. Some items were skipped, i.e., only one or two responses (instead of three) were made to a page; furthermore, it was impossible to establish a match between either an answer and the frame or between a component answer and the particular blank within a frame to which it applied. This made it impossible to evaluate the effectiveness of the programed materials in terms of an error analysis.

From general observations, it was quite apparent that too much repetition had been built into the program and that it was too redundant even for these mentally retarded students. The students unanimously expressed dissatisfaction with it by saying that the program kept asking the same questions over and over again. The amount of repetition had been guessed at since there was no a priori basis for making an accurate estimate of the students' needs. A formula was used to produce a consistent pattern of repetition. While several of the subjects said they liked to learn this way, they also said they didn't like to write the same words so many times.

Program Development: Principal Study

The experience gained from the pilot study helped to develop the procedure to the point where it was possible to take one more step toward automation of the frame writing. A moderate speed digital computer seemed ideally suited to the task of generating the frames of a teaching program from a proper code, a lexicon, and a set of instructions about frame sequence. In fact, the code itself could be generated, once the desired parameters were specified. In the present study, however, the code was written for each frame by the educational programer and punched into an IBM card. The computer program which was written did the work of translating the code into English, which previously the secretary in the pilot study had done.

AUTHOR: A computer program for automated frame writing. The program, AUTHOR (AUtomatic Translating of Heuristically Organized Routines) is a computer program written for the IBM 1620, of the Training Research Laboratory's SOCRATES.[3] Basically, it is a computer program which generates a set of frames of a teaching program from a coded input. A simplified flow chart for AUTHOR I is shown in Figure 1. The program automatically forms sentences, monitors the composition, and adjusts it, where necessary, to meet the grammatical requirements of conventional prose. For example, if one of the words that is a variable happens to begin with a vowel and is preceded by the word "A," then this ordinarily stable element of the sentence form is automatically converted to "AN." Similarly, variable elements in the sentence forms are pluralized where necessary.

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[3] AUTHOR I was written by Henry T. Lippert. SOCRATES is an acronym for System for Organizing Content to Review And Teach Educational Subjects.

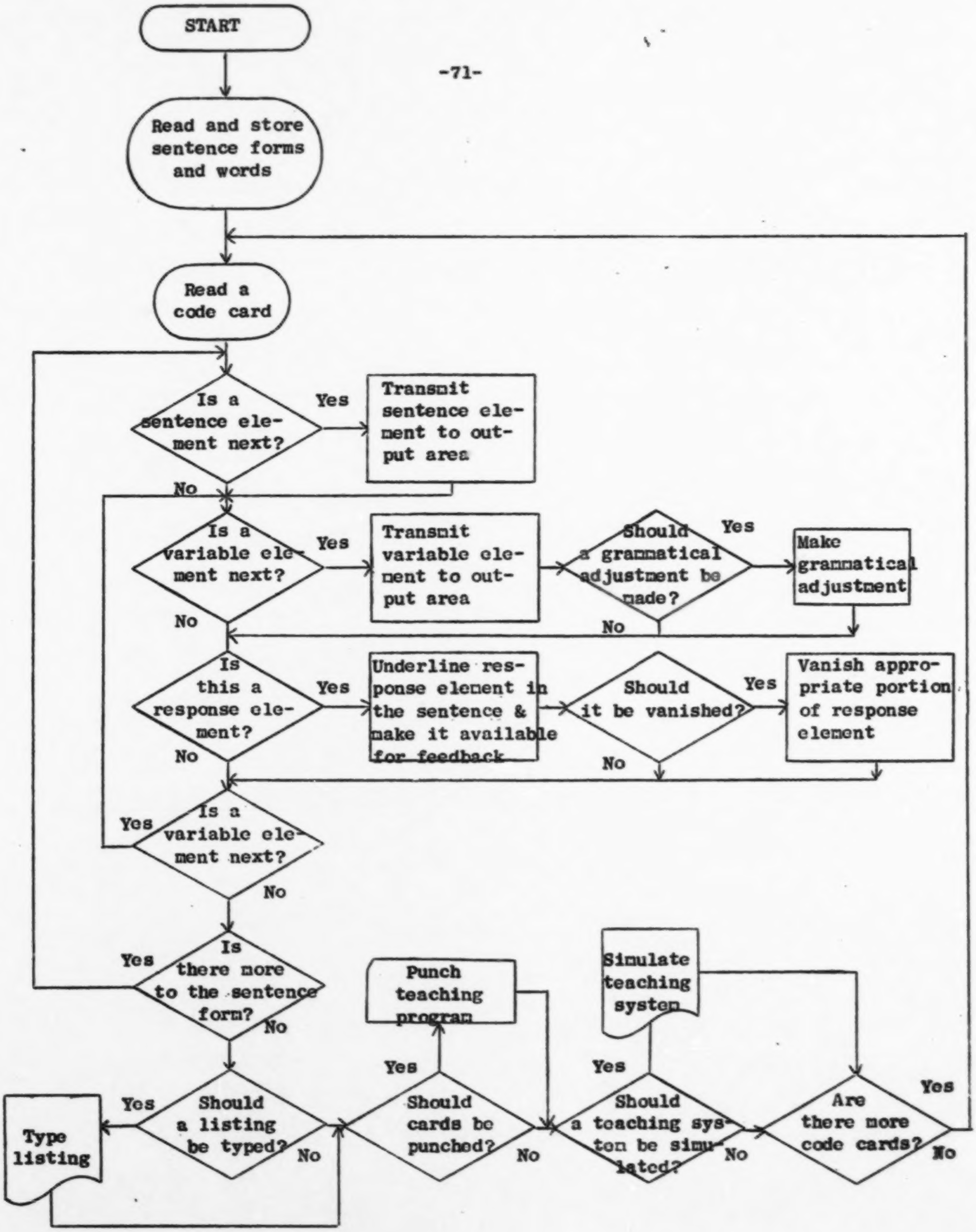
START
Read and store sentence forms and words
Read a code card
Is a sentence element next?
Yes
Transmit sentence element to output area
No
Is a variable element next?
Yes
Transmit variable element to output area
Should a grammatical adjustment be made?
Yes
Make grammatical adjustment
No
Is this a response element?
Yes
Underline response element in the sentence & make it available for feedback
Should it be vanished?
Yes
Vanish appropriate portion of response element
No
No
Yes
Is a variable element next?
No
Yes
Is there more to the sentence form?
No
Yes
Should a listing be typed?
No
Type listing
Yes
Should cards be punched?
No
Punch teaching program
Yes
Should a teaching system be simulated?
No
Simulate teaching system
Are there more code cards?
Yes
No

Figure 1. Flow chart for AUTHOR I.

Materials. The words chosen for use in this study were the same as those used in the pilot study (see Underwood and Richardson, 1956). The programed instructional frames used in this study, however, were generated by AUTHOR I. To reduce redundancy, a modified set of rules was used. The most obvious effect was that the number of frames was reduced considerably. The listings of the imput cards for AUTHOR I are included in Appendix A. The output of AUTHOR I is a set of punched cards which can be used to prepare stencils. A copy of the actual materials produced for this study by AUTHOR I for use by the students is included in Appendix B. The entire set of materials used in this study was generated in less than one-half minute by the computer.[4]

Experimental design. A treatments x subjects design (Lindquist, 1953, pp. 156-66) was used. Three factors entered into the Analysis of Variance. (1) The first factor was related to learning and was revealed by using a counter-balanced design so that the first half of the program could be compared with the second half. It is called LEARNING in the tables that follow. (2) The two association paradigms--many-to-one (M-1) and one-to-many (1-M)--were taught in two different sequences; (a) the one-to-many followed by the many-to-one (1-M, M-1) and (b) the reverse (M-1 then 1-M). These two sequences were a second factor in the design, and are called SEQUENCE in the tables that follow. (3) Attribute words and object words were used in the two association paradigms so that it was possible to determine whether each of these classes of words contributed uniquely to learning. This factor in the design was called ATT,OBJ in the tables that follow. The three factors were dichotomized. The experimental conditions were so arranged that the ordering of the factors was counterbalanced.

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[4] If SOCRATES had had enough I/O typewriters connected to it, the students could have been assigned to one, and the materials from which they learned would then have been typed directly at each typewriter. This would have eliminated the need to cut stencils and use the program in a device like the Koncept-O-Graph. Also, each student could have worked at his own rate, typed in his answer, and had it recorded and judged by the computer, and been told whether he was right or wrong. A highly successful use of AUTHOR I on an individualized basis is recorded in Chapter 7, pp. 196-207.

Procedure. A test preceded and followed the program. This test consisted of ten pages, sixty items of the form: "Think of some round things... A______ is round," etc. Six such blanks were provided for each of the "concept" words taught and for two words which were not taught (transfer terms).

Directions to the student were that he was to copy or fill in the word or words that were underlined. The first sentence of each direction of association for any word contained an un-vanished underlined response element which required only a copying response. Thus, the student was to read the sentence, copy the response element on the program itself, roll the program forward in the teaching machine (Min-MaxII) and compare his written response with the correct answer which then appeared in the window. The second sentence in every frame sequence that taught a direction of association contained response elements that were then vanished according to a particular set of rules. These three rules were: (a) When there are three response terms, vanish the same number of letters for all three, this number is not to exceed the number of letters of the shortest word of the three less one. (b) Always leave at least the initial letter of any response term: (c) Do not vanish more than five letters of any response term. The program was written so that the student's task was to copy the portion of the response word(s) which they were given as a prompt and to complete the word(s) by recalling all the missing letters. Thus, the students gave constructed responses to materials that initially provided prompts which were vanished on a definite schedule.

The program consisted of 32 sentences with a total requirement of 64 constructed responses. Within a sentence form the variable element in the predicate was designated the response term. An M-1 sentence was one that had a compound subject and a single predicate.

A sentence constructed in the M-1 direction contained three stimulus elements and one response element. A sentence organized in a 1-M direction had one subject and three predicate elements.

Subjects. The 24 subjects were students in a public junior high school[5] in Champaign, Illinois. Their mean chronological age and intelligence level (IQ mean, 70.2) are given in Table 2. The students were randomly assigned to four experimental groups.

RESULTS

Time

The mean time taken by the students to complete the tests and the program was 60.3 minutes with a standard deviation of 16 minutes. In an average of 15 minutes they learned 8 concepts and the spelling of 64 words. The correlations of total learning time with CA, MA, and IQ were -.13; +.04; and +.11, respectively. The correlations among these three subject variables and other performance measures are summarized in Table 3.

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[5] Grateful acknowledgement is made to Dr. Merle Karnes, Director of Special Services, and to Dr. Robert Cooley, Asst. Superintendent, for their permission, and to Dr. B. W. Thomason, Principal, to Mrs. E. H. Mellon and Mr. E. Broyles, teachers, for their cooperation in execution of this study. The data were collected and analyzed by Henry T. Lippert.

Table 2

Chronological Age and Two Intelligence Measures (N = 24)

	Mean	S.D.
Chronological Age	177.0[a]	9.8
Stanford Binet:		
Mental Age	123.7[a]	13.6
IQ	70.2	6.8

[a] Months

Table 3

Correlations Between Learning Time and Measures of Individual Differences on the Subjects (N = 24)

	CA[a]	MA[b]	IQ	T[c]
CA	1.00			
MA	.390	1.00		
IQ	-.113	.856	1.00	
T	-.132	.036	.107	1.00

[a] Chronological age

[b] Mental age

[c] Time

Performance Measures

The measures of learning were the change scores from the entry levels (pretest) to the final levels (posttest). The five change scores were: (1) number of responses; (2) number of correct responses; (3) number of responses made which were taught in the program; (4) the number of spelling errors made on "taught" words; and (5) the number of "taught" responses correctly made in sentences that did not appear in the program. The last of these measures served as a measure of transfer of training.

In addition to the change scores, the number of errors made in responding to the second sentence of each frame sequence was used as a measure of the efficiency of the program. This frame was the second one in each direction of association.

Each measure was analyzed twice, once to determine the total treatment effects (see Tables 4, 6, and 8) and again to determine the effect of each of the treatments and their interactions (see Tables 5, 7, and 9). The analysis shown in Tables 4 and 5, for both total effect and the effects of each treatment and its interactions, indicates that the number of responses the students made was not different for any of the factors under study. Similarly, Tables 6 and 7 indicate that the number of correct (appropriate) responses was not different for any of the treatments. Tables 8 and 9

Table 4

Analysis of Variance of Change Scores: Number of Responses Made by Students

Source	DF	Sum of Squares	Mean Square	F
Treatments	7	5.57812	.79687	.813
Subjects	23	38.74479	1.68455	
Treatments X Subject	161	157.79687	.98010	
Total	191	202.11979		

Table 5

Analysis of Variance of Change Scores: Number of Responses Made by Students with Partitioned Treatments Sum of Squares

Source	DF	Sum of Squares	Mean Square	F
Treatments				
A = Learng	1	1.50520	1.50520	1.535
B = M-1, 1-M	1	.13020	.13020	.132
C = ATT, OBJ	1	1.50520	1.50520	1.535
A X B	1	.00520	.00520	.005
A X C	1	2.29687	2.29687	2.343
B X C	1	.00520	.00520	.005
A X B X C	1	.13020	.13020	.132
Subjects	23	38.74479	1.68455	
Treatments X Subjs.	161	157.79687	.98010	
Total	191	202.11979		

Table 6

Analysis of Variance of Change Scores: Number of Correct Responses

Source	DF	Sum of Squares	Mean Square	F
Treatments	7	9.95312	1.38020	.877
Subjects	23	44.07812	1.91644	
Treatments X Subjs.	161	253.21354	1.57275	
Total	191	306.95312		

Table 7

Analysis of Variance of Change Scores: Number of Correct Responses with Partitioned Treatments Sum of Squares

Source	DF	Sum of Squares	Mean Square	F
Treatments				
A = Learning	1	5.67187	5.67187	3.606
B = M-1, 1-M	1	.13020	.13020	.082
C = ATT, OBJ	1	1.88020	1.88020	1.195
A X B	1	.04687	.04687	.029
A X C	1	.42187	.42187	.268
B X C	1	.00520	.00520	.003
A X B X C	1	1.50520	1.50520	.957
Subjects	23	44.07812	1.91644	
Treatments X Subjs.	161	253.21354	1.57275	
Total	191	306.95312		

Table 8

Analysis of Variance of Change Scores: Taught Responses

Source	DF	Sum of Squares	Mean Square	F
Treatments	7	4.16145	.59449	1.456
Subjects	23	19.74479	.85846	
Treatments X Subjects	161	65.71354	.40815	
Total	191	89.61979		

Table 9

Analysis of Variance of Change Scores: Taught Responses with Partitioned Treatments Sum of Squares

Source	DF	Sum of Squares	Mean Square	F
Treatments				
A = Learning	1	2.29687	2.29687	5.627**
B = M-1, 1-M	1	.13020	.13020	.319
C = ATT, OBJ	1	.63020	.63020	1.544
A X B	1	.00520	.00520	.012
A X C	1	.63020	.63020	1.544
B X C	1	.42187	.42187	1.033
A X B X C	1	.04687	.04687	.114
Subjects	23	19.74479	.85846	
Treatments X Subjs.	161	65.71354	.40815	
Total	191	89.61979		

** Significant at .01

show that the number of responses made to the posttest items which had been previously taught by the program when adjusted by those made prior to the teaching was not significantly different for the different treatment groups (Table 8). However, as revealed by Table 9 there was a significant difference in the number of such responses from the first half of the program to the second half. These data indicate that significantly more responses were made in reference to the second half of the program than to the first half. This difference can be interpreted as a learning-how-to-learn effect which is independent of the specific associative structure.

The number of spelling errors (change scores) made on the words which were taught by the program was not significantly different for any of the treatments as shown by Table 10 and 11 .

Learning Effects

The number of errors made (total spelling and omission) showed a significant decrease from the number of errors made on the first half to the number made on the second half. The total treatment effect, Table 12 , was significant and the analysis of the partitioned sums of squares for treatment effects indicated that the learning factor accounted for most of the variance, Table 13.

Table 10

Analysis of Variance of Change Scores: Spelling Errors on Taught Responses

Source	DF	Sum of Squares	Mean Square	F
Treatments	7	.16145	.02306	.310
Subjects	23	1.99479	.08673	
Treatments X Subjs.	161	11.96354	.07430	
Total	191	14.11979		

Table 11

Analysis of Variance of Change Scores: Spelling Errors on Taught Responses with Partitioned Treatments Sum of Squares

Source	DF	Sum of Squares	Mean Square	F
Treatments				
A = Learning	1	.00520	.00520	.070
B = M-1, 1-M	1	.04687	.04687	.630
C = ATT, OBJ	1	.04687	.04687	.070
A X B	1	.00520	.00520	.070
A X C	1	.04687	.04687	.630
B X C	1	.00520	.00520	.070
A X B X C	1	.00520	.00520	.070
Subjects	23	1.99479	.08673	
Treatments X Subjs.	161	11.96354	.07430	
Total	191	14.11979		

Table 12

Analysis of Variance of Errors Made on Learning Program

Source	DF	Sum of Squares	Mean Square	F
Treatments	7	11.14583	1.59226	2.099*
Subjects	23	116.72916	5.07518	
Treatments X Subjs.	161	122.10416	.75841	
Total	191	249.97916		

*Significant at .05

Table 13

Analysis of Variance of Errors Made on Learning Program with Partitioned Treatments Sum of Squares

Source	DF	Sum of Squares	Mean Square	F
Treatments				
A = Learning	1	4.68749	4.68749	6.180**
B = M-1, 1-M	1	.18749	.18749	.247
C = ATT, OBJ	1	2.08333	2.08333	2.746
A X B	1	1.68750	1.68750	2.225
A X C	1	.08333	.08333	.109
B X C	1	2.08333	2.08333	2.746
A X B X C	1	.33333	.33333	.439
Subjects	23	116.72916	5.07518	
Treatments X Subjs.	161	122.10416	.75841	
Total	191	249.97916		

**Significant at .01

Transfer Effects

For the transfer task, students made six responses to each of two words. One word was an attribute type and the other an object type. For this analysis, a word was counted as a transfer response if it was not used by the student to describe the same word on the pretest or if it was not one of the words taught during the program. Since only attribute words were used to describe objects and only object words were used to describe a set of attributes, the data were collapsed on the attribute-object dimension and subjected to a 2 x 2 analysis of variance. The results of this analysis are shown in Tables 14 and 15 . Neither of the two variables, learning to learn or the association-linkage paradigm, was significant in differentially determining successful transfer of the words taught to the new words.

DISCUSSION

The students increased significantly the number of responses they practiced in working with the program. This clearly demonstrated that the computer-written program was successful in teaching specific, but multiple, association linkages in both an M-1 and a 1-M direction. However, the effect of teaching the association paradigms in the two sequences--an M-1, then a 1-M or a 1-M, then an M-1-- was consistently the smallest of the three factors, however. This is interesting since

Table 14

Analysis of Variance of Change Scores for Use of Taught Words in Describing Concept Words Not Taught (Transfer)

Source	DF	Sum of Squares	Mean Square	F
Treatments	3	.53124	.17708	.635
Subjects	23	7.73958	.33650	
Treatments X Subjs.	69	19.21875	.27853	
Total	95	27.48958		

Table 15

Analysis of Variance of Change Scores for Use of Taught Words in Describing Concept Words Not Taught (Transfer) with Partitioned Treatments Sum of Squares

Source	DF	Sum of Squares	Mean Square	F
Treatments				
A = Learning	1	.01041	.01041	.037
B = M-1, 1-M	1	.01041	.01041	.037
A X B	1	.51041	.51041	1.832
Subjects	23	7.73958	.33650	
	69	19.21875	.27853	
Total	95	27.48958		

it is the first time that the paradigms have been compared under conditions that reveal the relative effects of associative structure independent of semantic or other associative factors.

Another interesting finding relates to semantic effects. The difference between the two classes of words--attribute and object--was not significant with respect to any of the measures of student performance. It would seem that in the maste of meaningful materials, e.g., concepts, this difference in the grammatical function of words is not highly related to the rate at which word-word relationships are learned.

The significance of the learning-how-to-learn effect shown by these retarded students is interesting, but hard to evaluate. Certainly they are learning something about the way they are to perform in this type of verbal learning situation. However, it is not clear from the available data what the nature of that learning is. When the study can be replicated on-line with a computer, it will be possible to obtain data that could reveal the nature of the learning-how-to-learn effect. For example, it would be possible to determine if they are learning that the associative sets involve a fixed number of S and R elements.

The present data suggest that the paradigm or associative structure itself is not a differential contributor to rate of acquisition since 1-M and M-1 were learned equally rapidly when M was equal to 3. It would seem that the advantage of stimulus generalization for learning lies in the pre-established associative significance of the elements (e.g., those making up a stimulus dimension) in the M-set for one another (see Stolurow, 1964). A verbal set such as "large," "larger," and "largest" represents a set of response terms which have pre-established associative significance for one another; however, a verbal set such as "long," "white," and "smelly" has neither established associative significance nor common elements. Consequently, a new association with one of them would not be expected to produce ready associations with the others. The only element they have in common is the cue-term. Obviously, their relationships with one another would require time to learn. On the other hand, terms with more common elements would be associated with one another. The purpose of the program used in this study was to establish new sets of relationships among terms that did not have common elements.[6]

If the learning rate for sets of items which are of the same size (e.g., 1-3) but have different associative relationships is compared, then it is possible to determine the effect of a particular semantic relationship on transfer. Other distinctions than these two can be made within word sets; sets are either arbitrarily related through a common association or they are related through a label which identified a continuum along which stimulus generalization or response generalization presumably could take place. If a distinction is made among types of associative relations -- new arbitrary sets, unordered but associated, and ordered and associated sets --- then at least these two can be studied in terms of possible generalizations. One type of study would see if, when one of the terms in a set is associated with a cue term, all, some, or none of the other terms in the set also can be elicited by that cue term. One would expect, for example, that in the arbitrary set each of the other terms would have to be associated with the cue term as a separate learning experience, but that this would not be true for the ordered sets for which either of two conditions, or both, would obtain. These are that the terms would have common elements (e.g., large, larger, largest) or they would be associated with an underlying "common element" which is ordinarily called a dimension.

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[6] The input cards for this program are listed in Appendix A. They pre- and post-test items are illustrated in Appendix B and the actual program seen by the students in Appendix C.

Another problem suggested by this analysis relates to the directions of association in the paradigm that are isomorphic with the stimulus generalization. This is the mirror image of the problem found in the paradigm of response generalization. This question of relative learning rate was examined only with M-sets that were small. It may be that one direction does have an advantage over its mirror image when the M-set is large. For both generalization paradigms, it is possible that the student is learning a set of 1-to-1 associations (see Mattson, 1961) when the terms are unrelated in past experience. However, when associative relationships exist, there is the question of whether these relationships equally facilitate learning regardless of the direction of association.

The difference between the M-1 and the 1-M paradigm is that of redundancy. In an M-1 paradigm, the responses are redundant; the same response is made to a set of different stimuli. In the 1-M paradigm, the reverse is the case, and the same stimulus term appears repeatedly with different response terms. In an M-1 paradigm, stimulus learning is required more than response learning; in a 1-M paradigm, response learning is more often required.

SUMMARY

In this study an attempt was made to do several things. One was to teach concepts and spelling to EMH students under conditions that could reveal the effects of structural differences in associative paradigms with respect to rate of learning. Another was to develop a method for using a computer to write programed instructional materials by using a code, a lexicon, and a heuristic routine. The study clearly demonstrated that this method is feasible since the EMH children learned not only the concepts taught, but also the spelling the terms defining the concepts. In addition, they learned how to learn as revealed by the increased rate of learning efficiency on successive concepts. The study also showed that, when Ss go from an M-1 associative paradigm to its mirror image, transfer effects are equivalent to those resulting when Ss go from a 1-M associative paradigm to its mirror image. Thus the associative structure in specific, but multiple, associative paradigms does not seem to produce an asymmetry in transfer effects.

These studies indicate the need for explicit rules to use in generating programs. The rules used here, while effective in getting students to learn, are not optimal, and in fact, do not use either ability data or Ss responses during learning in the preparation of frames. These rules can be built into the programing used by the computer in writing frames for constracted response programs.

APPENDIX A

ATTRIBUTE WORDS

ROUND@SOFT@HARD@SQUARE@	01A
LONG@WHITE@SMELLY@SMALL@SHINY@METALLIC@BIG@CLEAN@QUIET@	02A
NOISY@DIRTY@HEAVY@	03A

OBJECT WORDS

GRAPE@HEAD@BOULDER@PEACH@TONGUE@TOMATO@KNOB@BUTTON@STONE@	010
BOOK@WINDOW@CRACKER@	020
CIGARETTE@THIMBLE@HOSPITAL@CAR@	030

SENTENCE FORMS

A@OR@CAN BE A@THING.@	00000001F
A@OR@THING OFTEN IS A@.@	00000002F
A@OR@OFTEN IS A@THING.@	00000003F
A@OR@THING CAN BE A@.@	00000004F
A@THING OFTEN IS A@OR@.@	00000005F
A@CAN BE A@OR@THING.@	00000006F
A@THING CAN BE A@OR@.@	00000007F
A@OFTEN IS A@OR@THING.@	00000008F

CODE CARDS

```
F005@A011@0013,0011R@0012R@                    V0S1051-MC
F007@A011@0011,0012R@0013R@                    V3S1071-MC
F001@0011,0012@0013@A011R@                     V0S101M-1C
F003@0012,0013@0011@A011R@                     V3S103M-1C
F002@A021,A022@A023@0031R@                     V0S202M-1C
F004@A022,A023@A021@0031R@                     V5S204M-1C
F006@0031@A023,A021R@A022R@                    V0S2061-MC
F008@0031@A021,A022R@A023R@                    V3S2081-MC
F003@0014,0015@0016@A012R@                     V0S309M-1C
F001@0015,0016@0014@A012R@                     V3S311M-1C
F007@A012@0016,0014R@0015R@                    V0S3131-MC
F005@A012@0014,0015R@0016R@                    V4S3151-MC
F008@0032@A026,A024R@A025R@                    V0S4141-MC
F006@0032@A024,A025R@A026R@                    V4S4161-MC
F004@A024,A025@A026@0032R@                     V0S410M-1C
F002@A025,A026@A024@0032R@                     V5S412M-1C
F005@A013@0019,0017R@0018R@                    V0S5211-MC
F007@A013@0017,0018R@0019R@                    V3S5231-MC
F001@0017,0018@0019@A013R@                     V0S517M-1C
F003@0018,0019@0017@A013R@                     V3S519M-1C
F002@A027,A028@A029@0033R@                     V0S618M-1C
F004@A028,A029@A027@0033R@                     V5S620M-1C
F006@0033@A029,A027R@A028R@                    V0S6221-MC
F008@0033@A027,A028R@A029R@                    V2S6241-MC
```

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F003@0021,0022@0023@A014R@                         V0S725M-1C
F001@0022,0023@0021@A014R@                         V4S727M-1C
F007@A014@0023,0021R@0022R@                        V0S7291-MC
F005@A014@0021,0022R@0023R@                        V3S7311-MC
F006@0034@A033,A031R@A032R@                        V0S8301-MC
F008@0034@A031,A032R@A033R@                        V4S8321-MC
F004@A031,A032@A033@0034R@                         V0S826M-1C
F002@A032,A033@A031@0034R@                         V2S828M-1C
```

APPENDIX B

PRE-POST TEST ITEMS

THINK ABOUT YOUR NAME. WRITE YOUR NAME IN THE WINDOW.

THINK OF SOME ROUND THINGS. TURN THE KNOB AND WRITE THEM.

A ---------- IS ROUND.

A ---------- IS ROUND.

A ---------- IS ROUND.

A ---------- IS ROUND.

A ---------- IS ROUND.

A ---------- IS ROUND.

THINK ABOUT A CIGARETTE. TURN THE KNOB AND TELL SOME THINGS ABOUT IT.

A CIGARETTE IS ----------.

A CIGARETTE IS ----------.

A CIGARETTE IS ----------.

A CIGARETTE IS ----------.

A CIGARETTE IS ----------.

A CIGARETTE IS ----------.

THINK OF SOME SOFT THINGS. TURN THE KNOB AND WRITE THEM.

A ---------- IS SOFT.

A ---------- IS SOFT.

A ---------- IS SOFT.

A ---------- IS SOFT.

A ---------- IS SOFT.

A ---------- IS SOFT.

THINK ABOUT A THIMBLE. TURN THE KNOB AND TELL SOME THINGS ABOUT IT.

A THIMBLE IS ----------.

A THIMBLE IS ----------.

A THIMBLE IS ----------.

A THIMBLE IS ----------.

A THIMBLE IS ----------.

A THIMBLE IS ----------.

THINK OF SOME HARD THINGS. TURN THE KNOB AND WRITE THEM.

A ---------- IS HARD.

A ---------- IS HARD.

A ---------- IS HARD.

A ---------- IS HARD.

A ---------- IS HARD.

A ---------- IS HARD.

THINK ABOUT A HOSPITAL. TURN THE KNOB AND TELL SOME THINGS ABOUT IT.

A HOSPITAL IS ----------.

A HOSPITAL IS ----------.

A HOSPITAL IS ----------.

A HOSPITAL IS ----------.

A HOSPITAL IS ----------.

A HOSPITAL IS ----------.

THINK OF SOME SQUARE THINGS. TURN THE KNOB AND WRITE THEM.

A --------- IS SQUARE.

A --------- IS SQUARE.

A --------- IS SQUARE.

A --------- IS SQUARE.

A --------- IS SQUARE.

A --------- IS SQUARE.

THINK ABOUT A CAR. TURN THE KNOB AND TELL SOME THINGS ABOUT IT.

A CAR IS ----------.

A CAR IS ----------.

A CAR IS ----------.

A CAR IS ----------.

A CAR IS ----------.

A CAR IS ----------.

APPENDIX C

A ROUND THING OFTEN IS A BOULDER, GRAPE OR HEAD.

BOULDER GRAPE HEAD ------- ----- ----

A ROUND THING CAN BE A GR***, H*** OR BOUL***.

GRAPE HEAD BOULDER ----- ---- -------

A GRAPE, HEAD OR BOULDER CAN BE A ROUND THING.

ROUND -----

A HEAD, BOULDER OR GRAPE OFTEN IS A RO*** THING.

ROUND -----

A LONG, WHITE OR SMELLY THING OFTEN IS A CIGARETTE.

CIGARETTE ---------

A WHITE, SMELLY OR LONG THING CAN BE A CIGA*****.

CIGARETTE ---------

A CIGARETTE CAN BE A SMELLY, LONG OR WHITE THING.

SMELLY LONG WHITE ------ ---- -----

A CIGARETTE OFTEN IS A L***, WH*** OR SME*** THING.

LONG WHITE SMELLY ---- ----- ------

A PEACH, TONGUE OR TOMATO OFTEN IS A SOFT THING.

SOFT ----

A TONGUE, TOMATO OR PEACH CAN BE A S*** THING.

SOFT ----

A SOFT THING CAN BE A TOMATO, PEACH OR TONGUE.

TOMATO PEACH TONGUE ------ ----- ------

A SOFT THING OFTEN IS A P****, TO**** OR TO****.

PEACH TONGUE TOMATO ----- ------ ------

A THIMBLE OFTEN IS A METALLIC, SMALL OR SHINY THING.

METALLIC SMALL SHINY -------- ----- -----

A THIMBLE CAN BE A S****, S**** OR META**** THING.

SMALL SHINY METALLIC ----- ----- --------

A SMALL, SHINY OR METALLIC THING CAN BE A THIMBLE.

THIMBLE -------

A SHINY, METALLIC OR SMALL THING OFTEN IS A TH*****.

THIMBLE -------

A HARD THING OFTEN IS A STONE, KNOB OR BUTTON.

STONE KNOB BUTTON ----- ---- ------

A HARD THING CAN BE A K***, BUT*** OR ST***.

KNOB BUTTON STONE ---- ------ -----

A KNOB, BUTTON OR STONE CAN BE A HARD THING.

HARD ----

A BUTTON, STONE OR KNOB OFTEN IS A H*** THING.

HARD ----

A BIG, CLEAN OR QUIET THING OFTEN IS A HOSPITAL.

HOSPITAL --------

A CLEAN, QUIET OR BIG THING CAN BE A HOS*****.

HOSPITAL --------

A HOSPITAL CAN BE A QUIET, BIG OR CLEAN THING.

QUIET BIG CLEAN ----- --- -----

A HOSPITAL OFTEN IS A B**, CLE** OR QUI** THING.

BIG CLEAN QUIET --- ----- -----

A BOOK, WINDOW OR CRACKER OFTEN IS A SQUARE THING.

SQUARE ------

A WINDOW, CRACKER OR BOOK CAN BE A SQ**** THING.

SQUARE ------

A SQUARE THING CAN BE A CRACKER, BOOK OR WINDOW.

CRACKER BOOK WINDOW ------- ---- ------

A SQUARE THING OFTEN IS A B***, WIN*** OR CRAC***.

BOOK WINDOW CRACKER ---- ------ -------

A CAR CAN BE A HEAVY, NOISY OR DIRTY THING.

HEAVY NOISY DIRTY ----- ----- -----

A CAR OFTEN IS A N****, D**** OR H**** THING.

NOISY DIRTY HEAVY ----- ----- -----

A NOISY, DIRTY OR HEAVY THING CAN BE A CAR.

CAR ---

A DIRTY, HEAVY OR NOISY THING OFTEN IS A C**.

CAR ---

Chapter 5

PROMPTING VS. CONFIRMATION SEQUENCES AND OVERLEARNING IN THE AUTOMATED TEACHING OF SIGHT VOCABULARY[1]

PROBLEM

The determination of the intra-item sequence of events is fundamental to the programing of materials for automated instruction. The three events involved in intra-item sequencing are: (a) the cue-stimulus, the event to be associated with a new response; (b) the eliciting stimulus, the event that already has a high probability of eliciting the particular response to be connected with the cue-stimulus; and (c) the overt response, itself.

Prompting and confirmation are two sequences that laboratory research suggests might be effective means of organization in teaching by self-instructional programing. Although both sequences have proponents, there is a lack of supporting data which is based upon the teaching of meaningful materials and the testing of retention.

Prompting refers to a sequence in which the first event is the cue-stimulus, the second is the eliciting stimulus, and the third is the overt response. Confirmation refers to the sequence in which the cue-stimulus is first, the practicing of the overt response is second, and the eliciting stimulus is third.

Kopstein and Roshal (1954), Cook and Kendler (1956), Irion and Briggs (1957), Cook (1958), and Cook and Spitzer (1960), have obtained data that support the superiority of prompting over confirmation. Cook and Kendler (1956) account for their results in terms of the delay between the stimulus and the possibility of interference by the intruding responses.

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[1] Presented, in part, by Dr. L. M. Stolurow at the Annual Meeting of the Illinois Council of Exceptional Children, Chicago, Illinois, October 29, 1960, and at the XIV International Congress of Applied Psychology, Copenhagen, Denmark, August 17, 1961. The assistance and cooperation of the Illinois Department of Public Welfare and the personnel at Lincoln State School, Lincoln, Illinois, is gratefully acknowledged.

A third possible means of organization would be to use both prompting and confirmation procedures, first one and then the other, in a definite sequence. Angell and Lumsdaine (1960) used and compared a sequence in which both prompting and confirmation trials were used interchangeably with another sequence in which only prompting was used; they found the combined condition to be superior to pure prompting. Their explanation is that a training procedure that allows the learner to construct an answer in the absence of total "cue support" will be more effective than a procedure that provides continuous "cue support" throughout learning. Their position is that the learner should respond to the minimum value of the prompt that is sufficient to insure correct response. This position differs from that of Cook and Kendler (1956), who present an S-R contiguity position; however they began with a series of prompting trials that allowed a new association to build up before "cue support" was withdrawn and,in this respect, the two positions agree.

The use of a "Prompt S-R" and/or a "Confirmation S-R" procedure (Sidowski, Kopstein and Shillestad, 1961) is another method of implementing prompting and confirmation procedures. The "Prompt S-R" procedure is the same sequence as the prompting procedure, except that the second event in the intra-item sequence is a compound of the cue and eliciting stimuli (S and R terms) presented simultaneously, rather than just the response term (elicitor) presented alone; similarly, the "Confirmation S-R" procedure is the same sequence as the confirmation procedure (anticipation method) except that the third event in the intra-item sequence is a compound of the cue and eliciting stimuli, rather than just the response term alone; the S-R pair follows, rather than precedes, the learner's overt response. Consequently, it is said to be a confirming event rather than a prompt. The simple difference in the **Prompting** S-R and **Confirmation** S-R procedures is whether the S-R pair precedes (prompts) or follows (confirms) the overt response.

The issue raised by Angell and Lumsdaine (1960) can be viewed as a part of a larger and older psychology of learning, the issue of guidance. Carr (1930) has summarized the findings on guidance by indicating that it is more effective if provided early rather than late in learning. These older studies leave, at least, two important questions unanswered: (a) the effects that guidance has upon retention and (b) the relative effectiveness of guidance (prompting vs. confirmation) in relation to degrees of overlearning, since continued use of guidance or prompting is presumed to be less effective than initial use and early withdrawal (vanishing or fading).

PURPOSE

This study is concerned with determining possible differences in the effects of a Prompting S-R and a Confirmation S-R sequence upon the *learning* and *retention* of a sight voacbulary. A second concern is with the effect that different amounts of overlearning, under the Prompt S-R and the Confirmation S-R sequence, have upon retention.

Hypotheses

The position taken in the present research is that a "short circuiting" of response chains takes place as a basic process (see Osgood, 1953, pp. 353-399).

in learning. Responses originally elicited at one point in the behavior sequence appear earlier and earlier with practice. Events can interfere with short circuiting and, thereby, prevent the connection between the stimulus and the response that is interfered with from becoming as effective as it could be if allowed to move to a minimal contiguity condition.

Based upon previous research (Stolurow, 1961), and the contiguity and short circuiting concepts, the present research was designed to test the following hypotheses: (1) Prompting S-R would lead to more rapid learning than Confirmation S-R; (2) the number of trials required to achieve an overlearning level of 12 consecutive correct responses would be less than the number required to achieve an overlearning level of 24 consecutive correct responses; (3) the difference in level of performance under the two procedures would be *less* at the *higher* than at the lower level of overlearning; (d) the two sequences would not lead to retention effects that consistently favored the better learning method at the different levels of overlearning; (e) Prompting S-R would lead to better retention (as measured by recognition) than Confirmation S-R, since prompting is more like a recognition test; and (f) Confirmation S-R would lead to better recall than Prompting S-R, since Confirmation is more like the recall procedure.

METHOD

Subjects

All 40 subjects were institutionalized educable mentally handicapped (EMH) children in residence and attendance at the institutional Lincoln State

School, Lincoln, Illinois. Students were assigned randomly to one of four experimental conditions. Table 1 summarizes the group means for MA (in months) achievement in reading and arithmetic (in years and months), and PMA, (pretraining and posttraining in the sight vocabulary).

Design

The experimental design was a 2 x 2 factorial in which the two variables were: (a) intra-item sequence; and (b) overlearning. The four groups were: (a) P-12 -- Prompt S-R, with an overlearning criterion of 12 errorless trials; (b) C-12 -- Confirmation S-R, with an overlearning criterion of 12 errorless trials; (c) P-24 -- Prompt S-R, with overlearning of 24 errorless trials; and (d) C-24 -- Confirmation S-R, with overlearning of 24 errorless trials (see Figure 1).

Independent Variables

The Prompting S-R sequence is illustrated in Figure 2 , the Confirmation S-R sequence in Figure 3. The Prompting S-R sequence order of events was: (a) cue-stimulus frame, frame 1; (b) cue and eliciting stimulus in paired presentation, S-R frame, frame 2; and (c) discrimination frame, the requirement for an overt response, frame 3. In the Confirmation S-R sequence, the order of events was: (a) cue-stimulus frame, frame 1; (b) discrimination frame, frame 2; and (c) S-R frame, frame 3.

To implement the Prompting S-R sequence, a word (cue stimulus) appeared alone in the first frame; it was accompanied by its picture in the second frame

Table 1

Group Means for MA, Achievement, and PMA

Groups	N	Binet	Achievement		P.M.A. raw score means									
		MA	Read.	Arith.	Pretraining					Posttraining[a]				
		mo.	yr.mo.	yr.mo.	V	P	Q	Mo.	S	V	P	Q	Mo.	S
Separate														
Prompt - 12	7	89.57	1-7	1-8	40.29	22.14	15.00	43.86	13.43	$40\overset{+}{.}86$	$23\overset{+}{.}29$	$17\overset{+}{.}57$	$44\overset{+}{.}29$	$14\overset{+}{.}57$
Confirmation - 12	10	90.70	1-6	1-8	39.55	21.33	13.89	44.22	15.22	$45\overset{+}{.}22$	$27\overset{+}{.}89$	$18\overset{+}{.}67$	$45\overset{+}{.}44$	$18\overset{+}{.}11$
Prompt - 24	12	93.91	1-8	1-11	41.55	23.82	18.45	45.64	22.55	$47\overset{+}{.}18$	$24\overset{+}{.}91$	$19\overset{+}{.}55$	$46\overset{+}{.}64$	$17\overset{-}{.}64$
Confirmation - 24	12	90.91	1-10	2-0	40.37	23.55	18.64	56.00	15.91	$38\overset{-}{.}82$	$23\overset{+}{.}64$	$19\overset{+}{.}00$	$43\overset{-}{.}55$	$16\overset{+}{.}73$
Combined														
Prompt - 12 and 24	19	92.31	1-8	1-8	41.06	23.16	17.11	44.94	19.00	$44\overset{+}{.}72$	$24\overset{+}{.}28$	$18\overset{+}{.}78$	$45\overset{+}{.}72$	$16\overset{-}{.}44$
Confirmation - 12 and 24	22	98.18	1-9	1-10	40.00	22.55	16.50	50.70	15.60	$41\overset{+}{.}70$	$25\overset{+}{.}55$	$18\overset{+}{.}85$	$44\overset{-}{.}00$	$17\overset{+}{.}35$

---

[a] The + signs indicate increases and the - signs indicate decreases in scores.

Conditions	Groups	
	P-12	C-12
Sequence:	Prompting S-R	Confirmation S-R
Overlearning level:	12 correct	12 correct
	P-24	C-24
Sequence:	Prompting S-R	Confirmation S-R
Overlearning level:	24 correct	24 correct

Figure 1. Research design -- four groups with two sets of conditions.

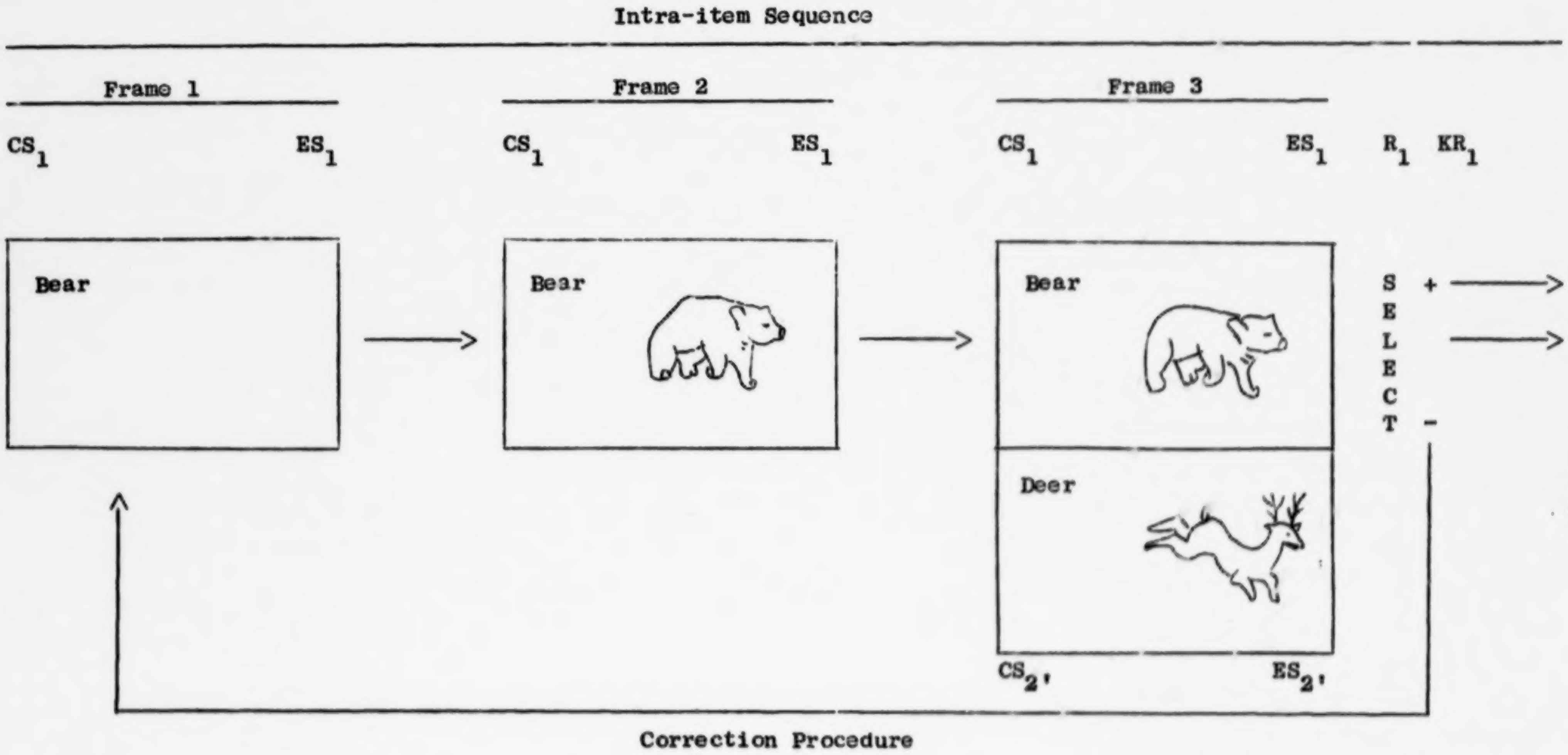
Intra-item Sequence
Frame 1
Frame 2
Frame 3
CS_1
ES_1
CS_1
ES_1
CS_1
ES_1
R_1
KR_1
Bear
Bear
Bear
Deer
CS_2'
ES_2'
S E L E C T
+
-
Correction Procedure

Figure 2. The Prompting S-R Sequence: Frame 1, cue frame; frame 2, cue-response (S-R) frame; frame 3, discrimination frame. CS_2'and ES_2'are used to identify the cue stimulus and eliciting stimulus respectively of the word taught and the "foil" used in building a discrimination.

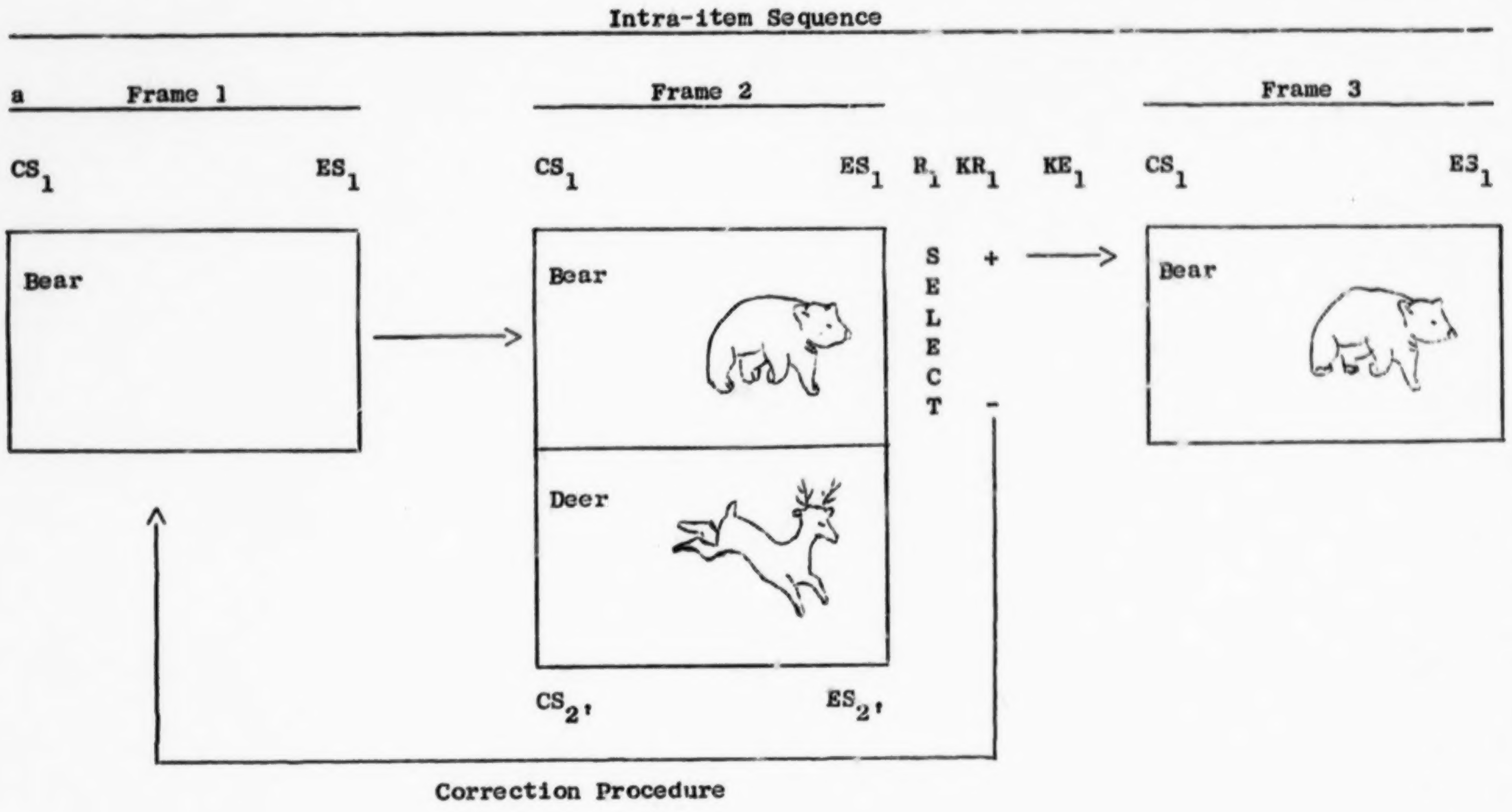
Intra-item Sequence
a
Frame 1
Frame 2
Frame 3
CS_1
ES_1
CS_1
ES_1
R_1
KR_1
KE_1
CS_1
ES_1
Bear
Bear
Deer
Bear
SELECT
+
-
$CS_{2'}$
$ES_{2'}$
Correction Procedure

Figure 3. The Confirmation S-R Sequence: Frame 1, cue frame; frame 2, discrimination frame; frame 3, cue response frame. $CS_{2'}$ and $ES_{2'}$ are used to identify the cue stimulus and eliciting stimulus, respectively of the word taught and the "foil" used in building a discrimination.

(paired presentation of cue and eliciting stimuli, or S-R frame); the discrimination frame (third frame) consisted of two word-picture pairs presented simultaneously, but, from trial to trial, their relative position was randomized, one above the other. The learner's overt response consisted of pointing to one of the pairs (the word taught or the foil). Identical materials were used to implement the Confirmation S-R sequence; however, it differed from the Prompting S-R sequence in the S-R and discrimination frame sequence.

Overlearning was manipulated by using two different "drop-out criteria" employed with the adjusted learning method (Woodworth, 1938), used along with the correction procedure.

Procedure

The five steps in the procedure were: (a) pretest of words and pictures; (b) administration of PMA; (c) training; (d) readministration of PMA; and (e) retention testing (See Figure 4 for the flow chart).

Pretest of words and pictures. Nouns which could be unambiguously pictured as simple line drawings were selected from the most commonly used words (Thorndike-Lorge, 1944). An initial set of 150 words were pretested to determine: (a) those that the children could not read; and (b) those which the children could identify a drawing of correctly. A list of 30 words that met these criteria were used. The list was divided into three sub-groups: (a) words taught without prior use; (b) words taught after being used as foils in the discrimination frame; and (c) words used only as foils. The words in

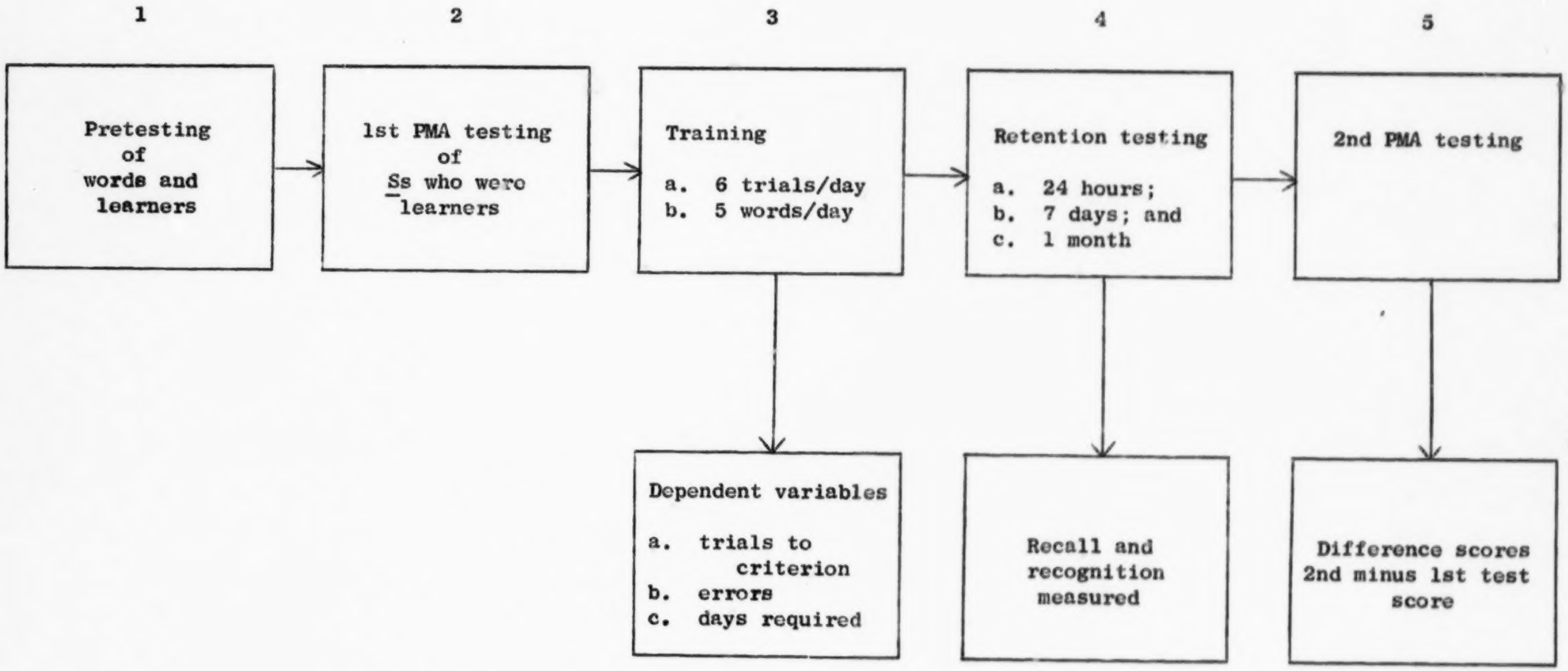
1
2
3
4
5
Pretesting of words and learners
1st PMA testing of Ss who were learners
Training
a. 6 trials/day
b. 5 words/day
Retention testing
a. 24 hours;
b. 7 days; and
c. 1 month
2nd PMA testing
Dependent variables
a. trials to criterion
b. errors
c. days required
Recall and recognition measured
Difference scores 2nd minus 1st test score

Figure 4. Flow chart of the experimental procedure.

group (a) were: glove, spoon, card, fork, hammer, boots, watch, tire, hand, candle, horse, leaf, guitar, cross, broom, flag, ring, button, and rope. The words in group (b) were further divided into: (1) those used twice as foils before being taught (i.e. eight, bear, chain) and (2) those used four times as foils before being taught (i.e. wheel, belt, and monkey). The words in group (c) were: rope, heart, dress, deer, wing, and rabbit. Of the 30 words, 25 were taught to the Ss and of the 25, six were taught after being used as a foil, and 19 were taught without having been used as foils. Of the six, three were used as foils twice, and three were used as foils four times before they were taught (See Figure 5).

Administration of PMA. The Thurstone PMA (1953 edition) (ages 5-7) was administered one to four days prior to the beginning of training, in accordance with standard procedure. It was readministered one week after training was accomplished.

Training. Every day each S was given five words to learn except at the very end of training when there were no replacements for the words that had been mastered. Every learner had 12 trials per day with each word, unless fewer trials were needed to meet the overlearning criterion, since criterion trials were cumulated from one day to the next.

Upon entering the room for the first time, each learner was

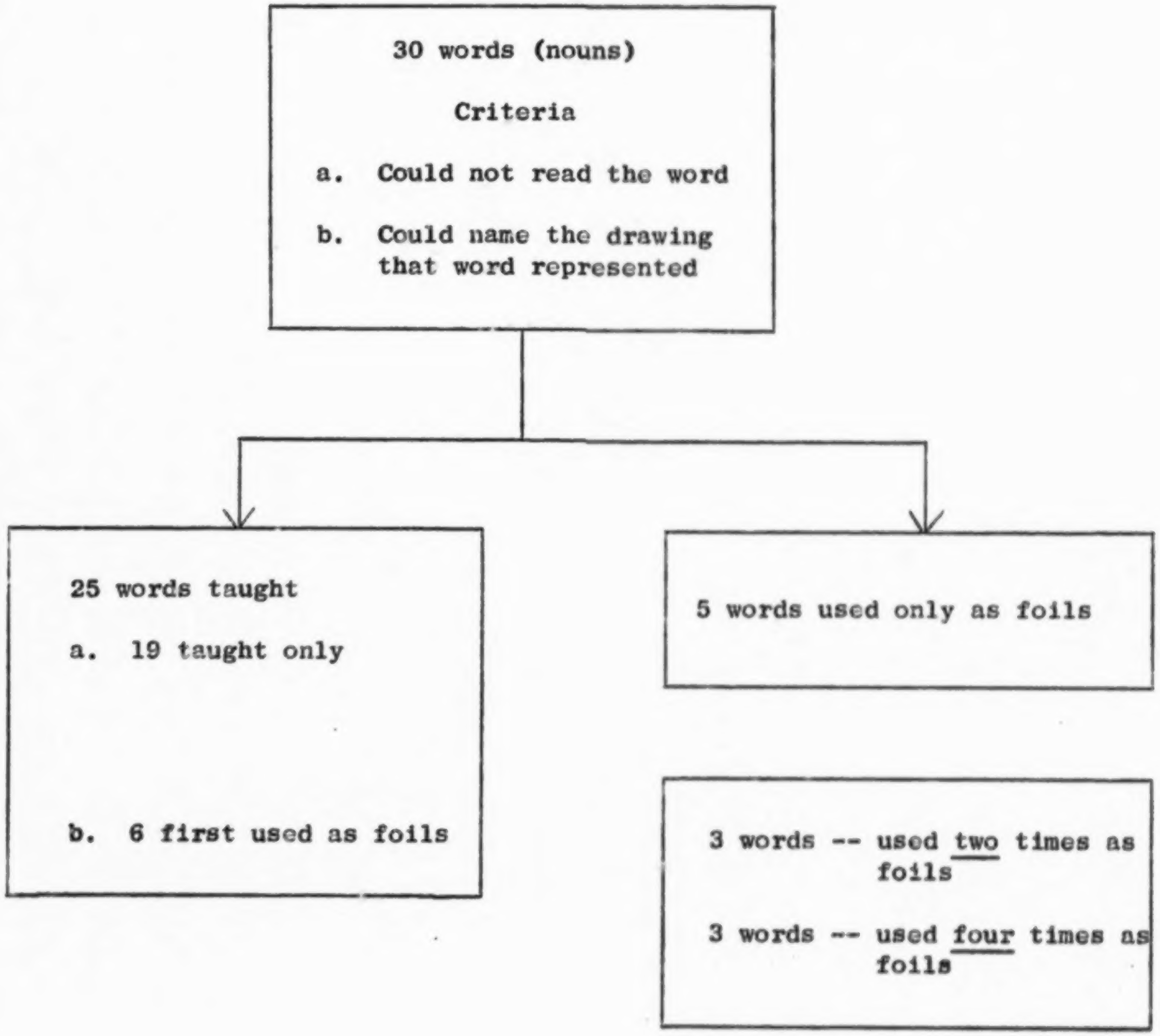
30 words (nouns)
Criteria
a. Could not read the word
b. Could name the drawing that word represented
25 words taught
a. 19 taught only
b. 6 first used as foils
5 words used only as foils
3 words -- used two times as foils
3 words -- used four times as foils

Figure 5. Use of words in the program.

seated, facing the experimenter, who first showed the word alone and said, "See this?"; after the child assented, the experimenter continued with, "I would like you to remember it." In the prompt condition, the word and picture were then shown together, and the experimenter said, "Look at this"; whereupon, he showed S two pairs of words and pictures and asked, "Which of these did you see before?" If the response was incorrect, S had an opportunity to try again; and this meant a representation of the cue word, the S-R pair, and the two pairs (discrimination frame). The procedure was repeated as many times as necessary for the correct response to be made (correction procedure). When the child responded correctly, the experimenter would say, "Uh huh," "That's right," "Okay," or "Good." Essentially the same procedure was followed for the confirmation procedure, except for the sequence (see Figure 3).

Each exposure, except for the discrimination frame, lasted approximately two seconds; however, the discrimination frame was exposed as long as necessary for a choice to be made.

Adjusted learning method. Every learner had to learn 25 words; however, he was given six trials per day on each of five words. The adjusted learning method (Woodworth, 1938) was used, i.e., five nouns were presented, one at a time, and each noun was considered separately in terms of the overlearning criterion. As the S reached criterion on a word, it was dropped out of the list and another one was substituted, except at the end of training when there were no more words to present. Therefore, only after the twenty-fifth word was presented, were fewer than five words taught.

Dependent variables. Effects of the four training conditions were used to determine three scores (to criterion): (a) trials; (b) errors; and (c) days required. It should be noted that the required criterion trials (i.e., 12 or 24) were not included in the scores used to evaluate training effects.

Retention Testing

Retention tests were given at three separate times after training was accomplished: (a) 24 hours after mastery; (b) 7 days after mastery; and (c) one month after mastery.

All words were tested by both recall and recognition procedures. A random sampling procedure, stratified on word length, was used to determine which words would be tested first for recognition, and second for recall; the other set was tested in the reverse order of recall, then recognition. This meant that for half of the children, the words used to test first for recall and then recognition were the same words used to test recognition first and recall second for the other half of the children. This was done to investigate the following findings reported by Postman, Jenkins, and Postman (1948);

(a) that recognition is poorer after recall than it is before recall; (b) that recall is better after recognition than it is before recognition, and (c) that when measuring retention, the temporal order in which recognition and recall data are obtained makes a difference in the scores provided by each method.

RESULTS

Data Obtained During Learning

Separate analyses of variance provided the findings for the two dependent variables: trials to criterion and errors. Both sets of results are presented in Table 2. The two dependent variables agree in revealing that the effects of prompting and confirmation procedures on performance differ; however, the interaction was not significant. The overlearning criteria did not result in significant differences with either dependent variable.

The first hypothesis, that Prompting produced faster learning than Confirmation, is supported by the data. Using the number of trials to a criterion as a measure of rate of learning the data that, on the average for 12 correct responses as the dependent variable, the Prompting S-R sequence took only 5.55 trials (see Figure 6). However, the Confirmation S-R sequence took 43.57 trials, over 7 times as many trials as Prompting S-R, to reach the same criterion. The group given Prompting S-R sequence took, on the average, 20 trials to reach the

Table 2

Summary of Analysis of Variance
Learning Data

Statistic	df	Dependent variables			
		Trials to criterion[a]		Errors to criterion[b]	
		MS	F	MS	F
Sequence	1	11,356.36	4.92[c]	2,735.27	12.11[d]
Overlearning	1	261.76		117.19	
Interaction	1	880.00		161.84	
Within	43	2,308.40		184.64	
Total	46				

[a] Means of groups: (a) P-12 = 5.55; (b) C-12 = 43.57;
(c) P-34 = 20,00; (d) C-24 = 46.83.

[b] Means of groups: (a) P-12 = 1.20; (b) C-12 = 19.21;
(c) P-24 = 4.90; (d) C-24 = 13.16.

[c] Significant at .05 level.

[d] Significant at .01 level.

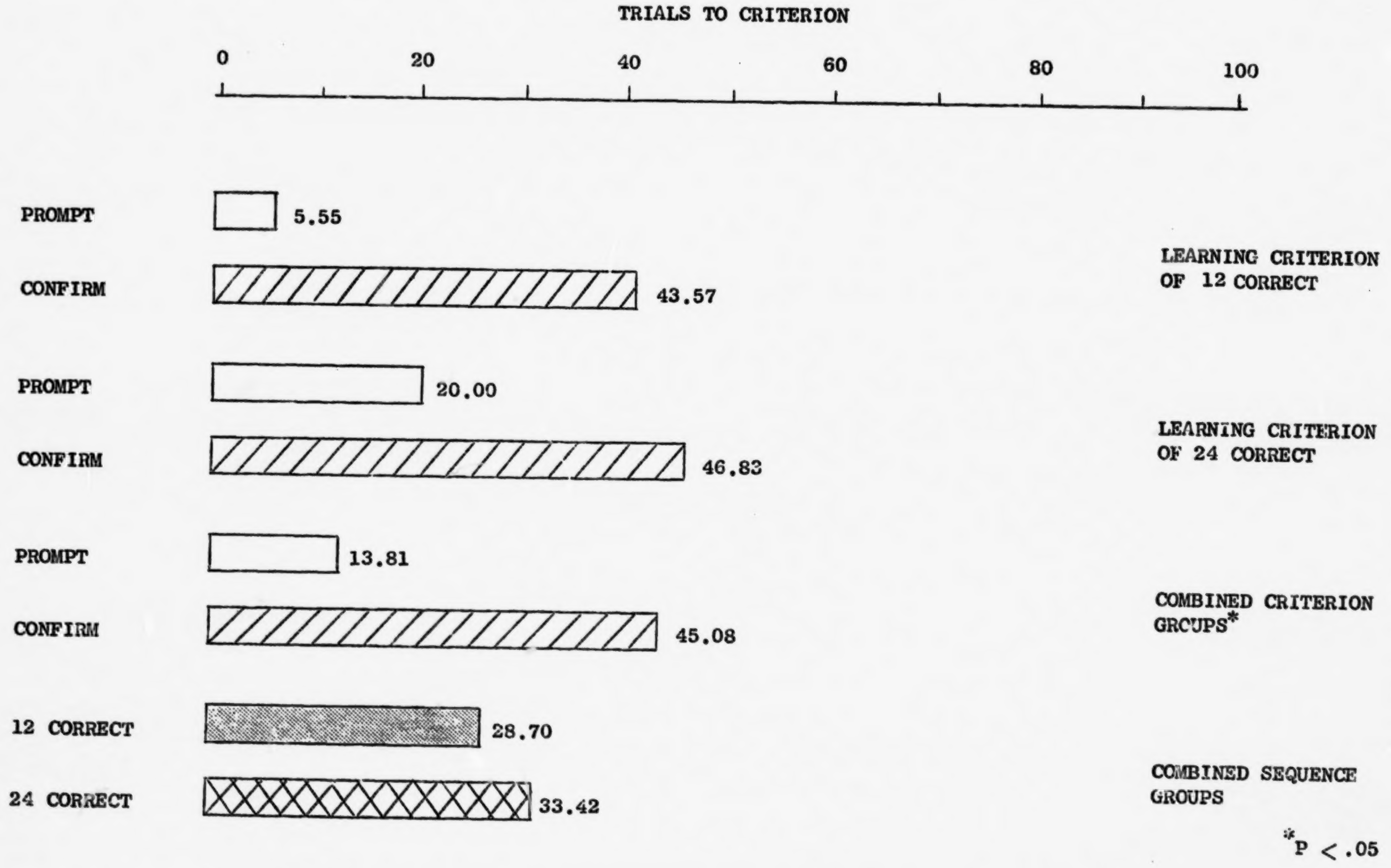

Figure 6. Mean number of learning trials required to reach each criterion of mastery (12 or 24 consecutive correct responses) under the prompting and the confirmation programing sequences.

overlearning criterion of 24 consecutive correct responses, whereas the group given the Confirmation S-R procedure took more than twice as many trials (46.83) to reach the same criterion (see Figure 6). For both criterion levels the Prompting S-R procedure resulted in fewer trials than the Confirmation S-R procedure. Combining the data for the two criteria levels indicates clearly the advantage of prompting (13.81) over the confirmation (45.08) as an intra-item sequence for learning. The difference between the two was significant beyond the .05 level.

Further evidence relating to the validity of hypothesis one comes from Figure 7. Prompting S-R resulted in a mean of 1.20 errors to reach the criterion of 12 correct responses, whereas Confirmation S-R resulted in a mean of 19.21 errors. At the higher criterion level of 24 correct responses, the mean values were 4.00 and 13.77, respectively. When combined, these means were significantly different ($p < .05$).

The second hypothesis, that the number of trials required to achieve an overlearning level of 12 consecutive correct responses would be less than the number required to achieve an overlearning level of 24 consecutive correct responses, is supported only by trends. In Figure 6, the mean number of trials to reach the criterion of 12 was 28.70 and that required to reach the criterion of 24 was 33.42.

Data Obtained for Retention

The third hypothesis, that performance level differences between P and C would be less at the higher than at the lower criterion level,

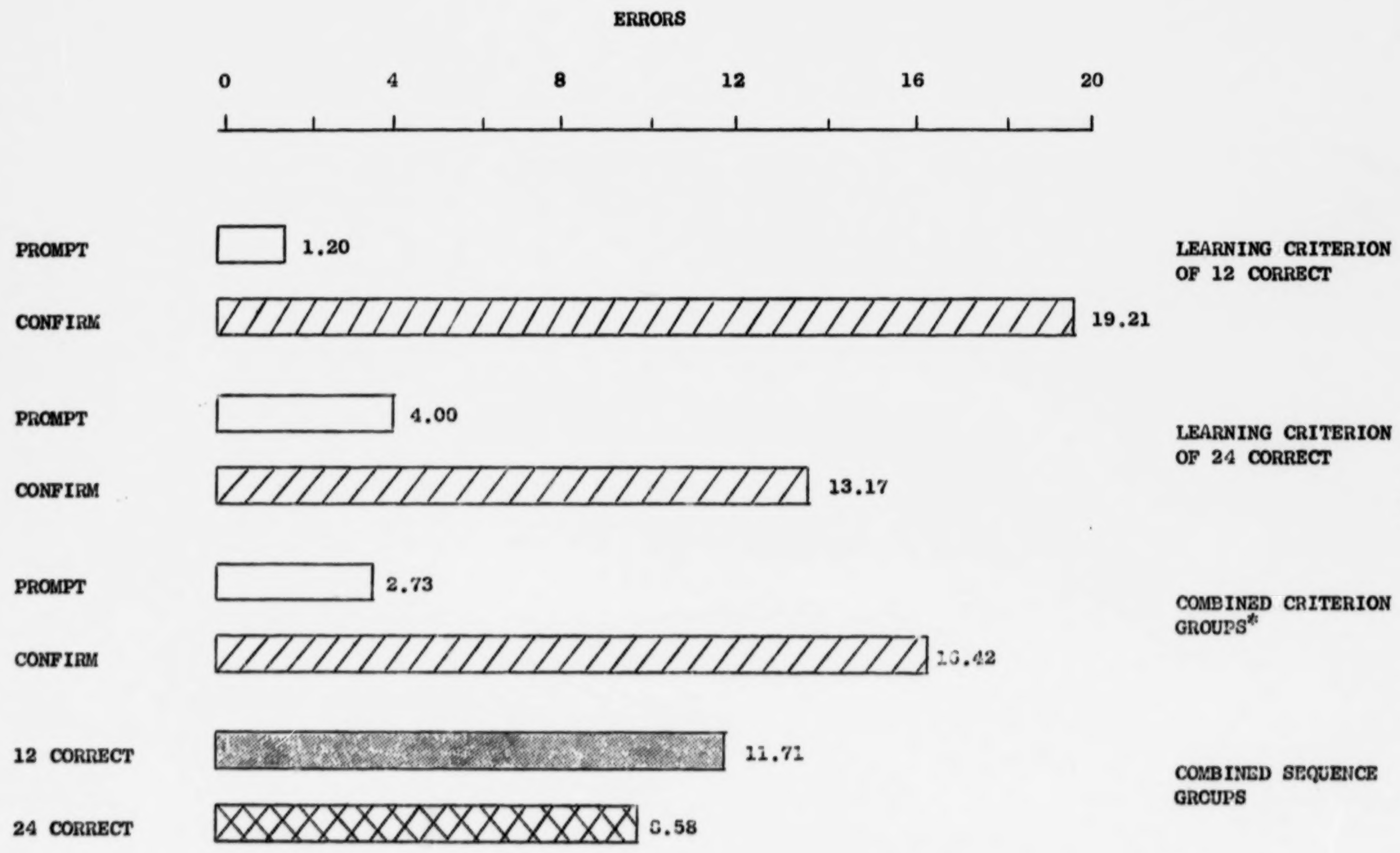

Figure 7. Mean number of errors made in learning to each criterion of mastery (12 or 24 consecutive correct responses) under the prompting and the confirmation programing sequence.

*$p < .05$

is not supported. The percentage difference of 29.2 correctly recalled for P-12 and C-12 is greater than the difference of 22.2 for P-24 and C-24; however, although the differences between the mean percentage of words correctly recalled favors the prompting condition at the lower criterion level, the difference favors the confirmation condition at the higher level. Consequently, the relative sizes of the absolute differences is deceptive. While the absolute difference is indeed greater at the lower criterion than at the higher level, the P-12 and C-12 difference is produced by the fact that Prompting S-R yields greater retention at the lower criterion level whereas the P-24 and C-24 difference is produced by the fact that Confirmation S-R produces greater retention at the higher criterion level.

The corresponding differences for recognition are 15.4 and 44.0, respectively. The absolute magnitude for the recognition differences is contrary to the hypothesis because the difference is greater at the higher criterion level. The recognition data support the recall data in revealing the superiority of the confirmation sequence at the higher criteria level and the superiority of the prompting sequence at the lower criteria level.

Table 3 indicates the average number of days required to teach the children 25 words. The means vary from a low of 5.20 days for the P-12 group to a high of 11.63 days for the C-24 group. The

Table 3

Average Number of Days Required to Learn 25 Words
Under Each Experimental Condition

Average	P-12	C-12	P-24	C-24
Mean	5.20	6.60	10.52	11.63
Median	5.14	6.34	10.64	10.84

medians show the same trend.

The comparisons of the rates at which the different groups of words were learned were uninformative (see Table 4). For example, there were no differences in the rates at which the following word groups were learned: (a) those taught without first being used as foils; (b) those taught after being used two times as foils; (c) those taught after being used four times as foils.

The fourth hypothesis, that the two sequences would not lead to retention effects that favor the better learning method at both overlearning levels, was supported by the data. While at the lower level, Prompting S-R was better for learning and also produced better retention, at the higher overlearning level, Prompting S-R produced better learning but Confirmation S-R produced better retention.

Results of both recall and recognition scores on the 24 hour retention test (see Figure 8) support the fifth hypothesis that the Prompt S-R sequence leads to better recognition performance than the Confirmation S-R sequence when measured after the lower overlearning level. However, with the higher overlearning level, the Confirmation S-R sequence produced, thereby leaving the hypothesis unsupported for the higher overlearning group.

The Confirmation S-R sequence led to better performance on the recall test only in the higher overlearning level; this supports the sixth hypothesis, that Confirmation S-R would lead to better recall than would Prompting S-R. Contrary to this hypothesis, however, at the lower overlearning level the Prompting S-R sequence produced better recall than Confirmation S-R sequence.

Table 4

Mean Percentage of Correct Responses at Three Different Test Intervals

		After 24 hours								After 7 days				After 1 month			
		WORD				FOIL				WORD				WORD			
		Recall		Recognition		Recall		Recognition		Recall		Recognition		Recall		Recognition	
Group[a]	N	+ Set	0 Set	÷ Set	0 Set	+ Set	0 Set	+ Set	0 Set	+ Set	0 Set	+ Set	0 Set	÷ Set	0 Set	÷ Set	0 Set
P-12 A	4	50.0*	75.0	81.2	80.8*	56.2*	28.8	58.5	52.0*	59.8*	45.8	67.2	78.5*	31.2*	46.2	54.0	53.8*
P-12 B	6[a]	63.6	64.3*	76.6*	83.6	44.6	51.0*	64.1*	65.8	45.5	58.1*	75.3*	62.6	75.0	43.2*	78.2*	78.6
C-12 A	6[b]	20.8*	58.8	66.3	72.1*	29.7*	11.5	34.2	35.2*	55.1*	24.3	69.1	55.8*	11.4*	44.6	53.4	47.6*
C-12 B	8	50.9	30.6*	61.2*	58.6	22.5	32.6*	37.4*	38.2	34.2	48.1*	61.1*	56.3	39.8	28.0*	42.8*	50.0
P-24 A	6[c]	52.8*	65.5	73.5	69.3*	48.6*	37.2	51.3	52.5*	63.8*	44.6	70.8	71.8*	41.5*	61.5	68.8	63.2*
P-24 B	6[b]	25.2	48.8*	41.5*	64.3	30.7	23.3*	39.7*	43.0	30.8	33.5*	47.5*	51.6	43.2	30.6*	53.2*	55.4
C-24 A	6[b]	75.0*	84.6	90.8	86.1*	68.6*	58.5	70.0	72.8*	84.6*	71.0	87.3	83.8*	56.6*	67.6	78.2	67.8*
C-24 B	6	55.5	71.0*	85.5	78.8	45.0	33.0*	54.0*	51.3	60.5	57.3*	77.6*	76.3	62.7	44.8*	72.2*	61.9

[a] The A and B following the group designation indicates the sub-groups used in assigning priority to the recall and recognition tests words. For example, P-12 A was tested on the ÷ Set of words first by recall and then by recognition, and on the 0 Set of words they were tested first by recognition and second by recall.

[b] One less S at 1 month test.

[c] Two less S at 1 month test.

*Indicates the mean % obtained when recall was tested first.

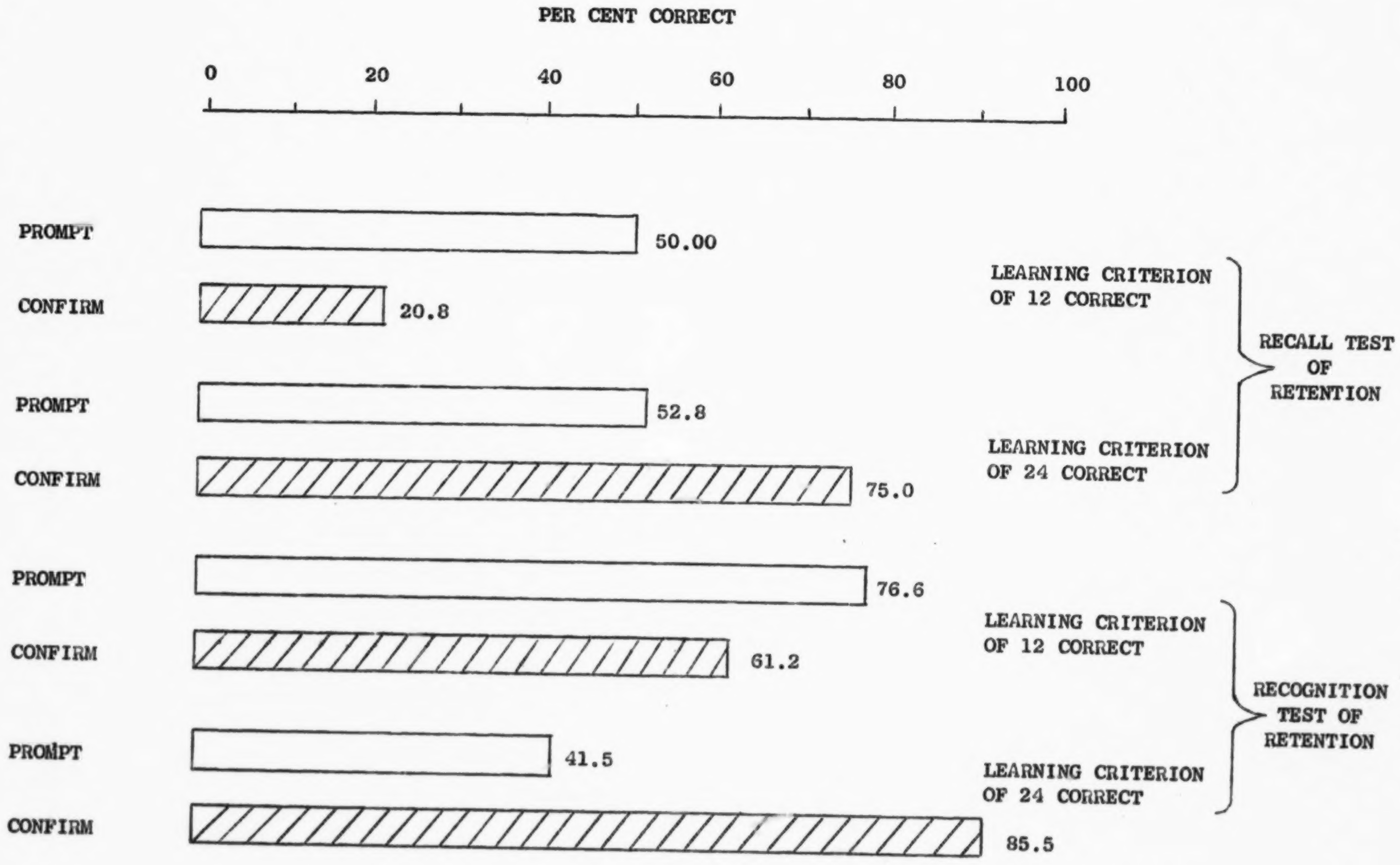

Figure 8. Percentage of words retained after 24 hours.

Since some findings are contrary to the fifth and sixth hypothesis, the data casts doubt on the bases for these hypotheses, i. e., that the retention test that was most similar to the learning condition would show the highest scores. In other words, it was assumed that Confirmation involved more recall and that Prompting involved more recognition; therefore, each procedure would favor the corresponding retention testing method. However, contrary to hypotheses five and six, the retention data suggest that it is not simply a matter of similarity between training and testing conditions that is important, but that the intra-item sequence to be the more important factor determining the degree of retention at the higher overlearning level. This is consistent with the prediction based upon the "short circuiting" principle. At the lower overlearning level, on the other hand, the Prompting S-R sequence led to consistently better performance with both recall and recognition tests. Thus, the effect which both the prompting S-R and the Confirmation sequence have upon retention seems to depend upon the amount overlearned.

Also, the most effective procedure for learning, the Prompting S-R sequence, in this case, is not always the most effective for retention. With higher overlearning, the Confirmation S-R sequence was more effective for retention in both recall and recognition.

Another question is whether or not the interaction between variables persisted. Although the data are attenuated by the fact that they were obtained as a result of repeatedly testing the same learners, they have some significance since the students were given no knowledge of results and had no opportunity to practice between tests. In spite of this, the differential effect of the training conditions was found to persist. The retention scores obtained after 7 days verify the pattern of results obtained by the retention tests given earlier (see Figure 9). The Prompting sequence was better with the lower overlearning level, but the Confirmation sequence was better with the higher overlearning level.

The data obtained after a one-month retention interval (see Figure 10) further support the previously reported findings that retention depends upon both the sequence used and the amount of overlearning. Prompting is more effective with lower overlearning levels, and Confirmation is more effective with higher overlearning levels.

The data obtained after 24 hours were used to see if the following effects, reported by Postman, Jenkins, and Postman (1948), obtained: (a) recognition was poorer if measured after than it was if measured before recognition testing in five out of eight comparisons. Contrary to Postman, Jenkins and Postman's findings recognition was better when measured after recall than it was when measured prior to recall in five out of eight comparisons. These data suggest that the second (recognition or recall) is more likely to be higher than the first mean, regardless of which one was determined first. The difference between the recognition and recall means

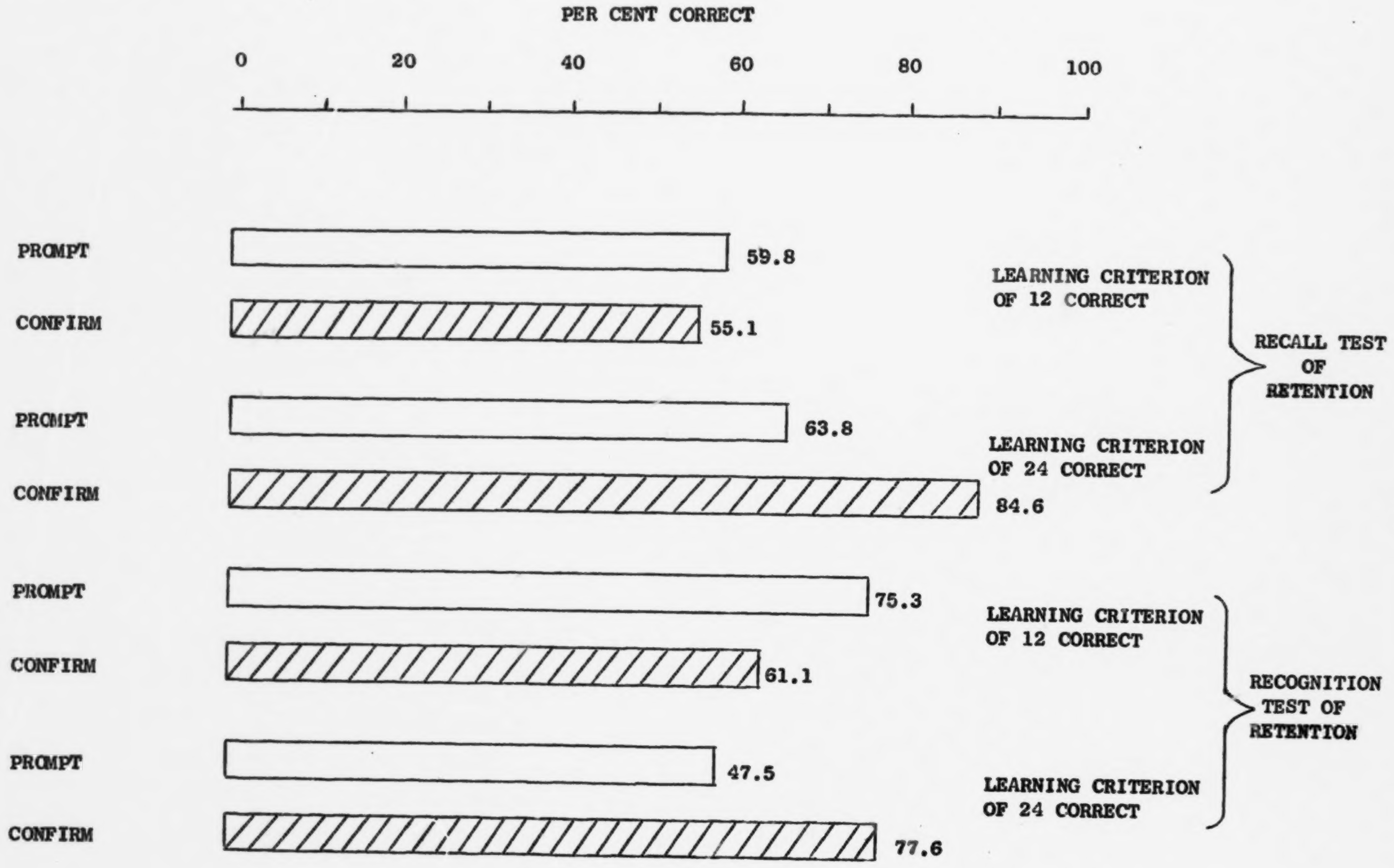

Figure 9. Percentage of words retained after 7 days.

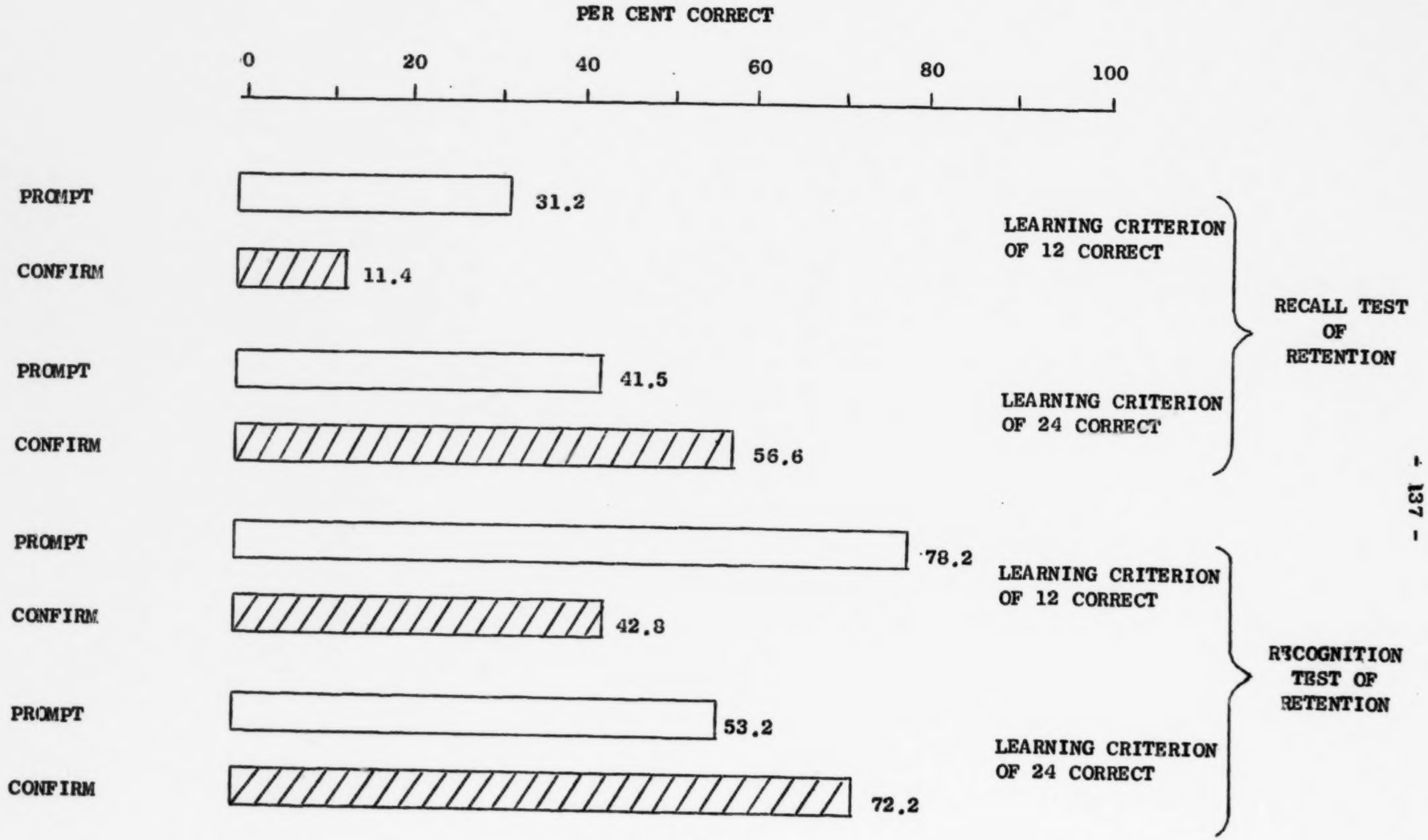

Figure 10. Percentage of words retained after one month.

was larger, on the average, when recall was tested second (59.5 percent); the difference between the two means was smaller when recall was tested first (14.0 percent) (See Table 5).

DISCUSSION

The few relevant studies (Cook and Kendler, 1956; Cook, 1958; Cook and Spitzer, 1960; Sidowski, Kopstein, and Shillestad, 1961) have indicated the superiority of a Prompting sequence over a Confirmation (anticipation) sequence for the learning of paired associates. Cook and Kendler (1956), who have conceptualized paired-associate learning as a two-stage process, predict the superiority of the Prompting S-R sequence in terms of temporal continguity. In other words, according to the theory proposed here, a Prompting S-R sequence is more efficient for learning because the correct response follows the cue term more immediately than it does with a Confirmation S-R sequence; the correct response is more likely to be delayed with a Confirmation S-R sequence. This is particularly true early in learning when the connection is weak and the anticipatory response is likely to be incorrect. These factors may interfere with efficient association of cue and response which could explain why the Prompting S-R sequence is better than the Confirmation S-R sequence.

Table 5

Summary of Mean Retention Scores (Percentage) of Words

Group	Recall			Recognition		
	1 day	7 days	30 days	1 day	7 days	30 days
P-12	50.0	59.8	31.2	76.6	75.3	78.2
C-12	20.8	55.1	11.4	61.2	61.1	42.8
P-24	52.8	63.8	41.5	41.5	47.5	53.2
C-24	75.0	84.6	56.6	85.5	77.6	72.2

Note: -- Percent signs have been omitted.

Angell and Lumsdaine (1960) studied a mixed Prompting-then-Confirming sequence and found evidence for the superiority of a mixed over a pure Prompting sequence. They also found pure Prompting to be superior to unmixed Confirmation for learning. Although they implemented Prompting and Confirmation differently from the way it was accomplished here, their results support the learning data obtained in the present study. When combined with the present findings on retention, they suggest that complex, rather than simple, teaching methods are required to accomplish the dual educational objectives of rapid learning and superior retention. The learning situation should be designed to make the probability of the correct response as high as possible at the early stages of learning, e.g., Prompting; however, the prompt, or eliciting stimulus, has to be withdrawn if high levels of overlearning are used. This implies a shift to confirmation procedure. Evidence of the greater efficiency of Confirmation procedure with higher degrees of overlearning is that it improves retention. This suggests that the prompt should be withdrawn once the correct response becomes highly probable; the Confirmation procedure should then be used to allow the learner to practice under conditions which allow short circuiting to take place. Short circuiting takes place more rapidly when prompts for the response are withdrawn. The reinforced response can be more effectively transferred to the cue if the prompt is withdrawn so that the cue is used alone; this permits the response to occur with greatest continuity with the cue stimulus, and this makes the cue-response connection more effective for both retention processes, recall, and recognition.

SUMMARY

The present results, obtained in teaching a sight vocabulary to educable mentally retarded subjects, support those of other investigators who used related procedures, but different materials and subjects. They substantiate the hypothesis that a Prompting S-R sequence produces more rapid learning than a Confirmation S-R sequence. The data also extend previous research findings by indicating that the relative level of retention, resulting from these two sequences, differs depending upon the amount of overlearning involved. The Prompting S-R sequence results in both better recall and better recognition, for as long as one month, when the amount of overlearning is neglibible, whereas the Confirmation S-R sequence results in both better recall and recognition, for as long as one month, when the amount of overlearning is appreciable. The results support the theoretical position presented.

An important pedagogical implication of the study is that neither Prompting nor Confirmation, when used alone, will produce both rapid learning and better retention. Therefore, a proper mixture is needed to achieve both of these objectives. The findings reveal the pedagogical dangers in the assumptions that (a) a method which produces better learning also produces better retention, and (b) a method will be relatively more efficient than another in its effects on retention under all degrees of overlearning.

Chapter 6

PROMPTING, CONFIRMATION AND VANISHING IN THE AUTOMATED TEACHING OF A SIGHT VOCABULARY[1]

PROBLEM

The sequencing of events to teach efficiently a single association, such as that involved in correctly labeling a printed word, is an important, basic problem in programing materials for automated self-instructional devices. The research reported in Chapter 5 examined the problem. This chapter describes additional research concerned with the problem of intra-item sequencing and is related to the teaching of a sight vocabulary. More specifically, it describes research dealing with the combined use of two intra-item sequences which produce a type of vanishing when used together.

Like Chapter 5, this is a study of the "fine grain" of teaching procedures, or strategies in order to determine the implications of a theoretical position within a practical instructional context. The procedures involve respondent conditions, and, among other practical applications, could be useful in sequencing the molecular events used to teach any paired associate, e.g., a vocal response to a printed word, the date of an historical event, or the square of a number.

The research in Chapter 5, on the teaching of a sight vocabulary to educable mentally retarded children, indicates that the specific stimulus sequence that is used can have significant effects as measured by both recall and recognition procedures on both the rate at which learning takes place and the level of retention that results.

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[1] Parts of this paper were presented by Henry T. Lippert at the annual meeting of the Council for Exceptional Children, Columbus, Ohio, 1962, and by Lawrence M. Stolurow at the annual meeting of the American Association on Mental Deficiency, New York City, 1962.

THEORETICAL CONSIDERATIONS

Prompting and Confirmation

If the operations involved in prompting and confirmation are related to those used in earlier work on guidance (Carr, 1930), then the procedure employed to give the learner guidance is, in effect, the use of an eliciting stimulus; and the withdrawal of guidance is removing the guidance in the stimulus support and it is called vanishing. The prompting sequence can be thought of as maximizing guidance; the confirmation sequence, as minimizing guidance; and the combined use of prompting followed by confirmation is thought of as the removal of guidance, or a form of vanishing. A shift from a prompting to a confirmation procedure is a single-stage vanishing procedure and, thereby, differs from some of the vanishing and fading procedures that have been used in programed learning. Contrary to Angell and Lumsdaine's interpretation (1960) in the research reported here, the position taken is that vanishing involves the reduction of the eliciting stimulus rather than the reduction of the cue stimulus. This interpretation relates to the distinction between these two stimulus functions which was described earlier. It seems desirable to reserve the term cue stimulus for the minimum stimulus required to define the necessary and sufficient conditions for a particular response when the subject is performing the task at criterion level.

This difference in interpretation leads us to conclusions different from those of the studies that have been conducted and to different study designs. For example, in essence, it supports Cook and Kendler's (1956) analysis which says that the contiguity of cue and response is the critical factor accounting for observed differences in the resulting behavior. It also says that Angell and Lumsdaine (1960) are correct in that the withdrawal of the prompt or eliciting stimulus is important. However, the present position asserts that the effect of vanishing is to produce progressively greater contiguity of cue and response as learning progresses to higher and higher levels of overlearning. With a Confirmation procedure, the response can appear as soon after the cue is available as physiological mechanisms will allow. Thus S-R Contiguity can become minimal through the process of short circuiting.

As was found in the first study of Prompting and Confirmation (Chapter 5), it is possible with the Prompting S-R sequence to achieve a high probability of correct response in relatively close contiguity with the cue stimulus quite early in learning. As learning goes on, however, the cue stimulus acquires the capability of eliciting the response in its own right so that still greater degrees of contiguity can be achieved if the student is allowed to make the overt response immediately. The theory proposed here is that the student is able to transfer response from the elicitor to the cue more efficiently if the eliciting stimulus is withdrawn than if it is continuously interposed between the cue and the response. In short, the theory used here asserts that the confirmation procedure allows the student to reach a faster overt response rate than the prompting procedure does.

Viewing the problem in the perspective of the theoretical position taken in these studies, the Prompting S-R sequence produces a high initial probability of correct response and a relatively brief S-R interval early in practice. When the Prompting S-R sequence is continued, however, the associative connections formed between the cue and the response are not as strong as they are if the prompting S-R frame is withdrawn. Continued use of the prompting S-R frame prevents the association between cue and response from becoming as strong as it possibly can because the presence of the prompt introduces an interval between S and R so that maximum S-R contiguity cannot be achieved.

The Confirmation S-R sequence, on the other hand, produces slower initial learning because the correct response is less probable than it is with the Prompting S-R procedure. Once the cue-response association is established, however, this association can achieve higher levels of contiguity than are possible with the prompting procedure. Therefore, the Prompting S-R sequence is effective if used at first; but, if it is used for too long a time, the strength of association will not increase to its maximum. In fact, the student will learn to delay his response for the interval of time imposed by the inserted prompting stimulus. The intervening prompt introduces a delay in a short circuiting process; it interferes with the minimizing of the S-R interval. The previously reported superior retention of associations that are highly overlearned under the Confirmation S-R training supports this interpretation which is that prompts interfere with short circuiting. The problems for research are to determine (a) the amount of Prompting S-R training to give before changing to Confirmation S-R training and (b) the amount of Confirmation S-R training necessary to give so that long term retention will be produced.

Vanishing

The data and this theoretical analysis suggest that the procedure of vanishing the eliciting stimulus might permit the best effects of the two sequences to be obtained by combining them in some, as yet, unspecified proportion. Consequently, this study was designed to determine the learning and retention effects of different combinations of Prompting S-R procedure followed by

Confirmation S-R procedure. Each combination was considered as a vanishing condition in which different numbers of Prompting S-R trials were followed by different numbers of Confirmation S-R trials. The ideas discussed earlier suggest the possibility of an optimum combination of Prompting S-R followed by Confirmation S-R to achieve the best combination of learning and retention.

METHOD

Subjects

The 25 educable mentally handicapped (EMH) children who served as subjects in this study were from special education classes in an Urbana, Illinois, public school.[2] During the time required to collect the data, six of the 25 children were unavailable for various reasons and had to be dropped from the subsequent data collection and analysis. CA, Stanford Binet MA, and Peabody Picture Vocabulary MA scores are summarized in Table 1.

These children were younger in CA and MA than those used in the first study and all had MA's below that of the maximum of a beginning first grader in a regular class. In fact, in MA, the group falls into two levels: (a) the lower level, or pre-school MA level sub-group; and (b) the higher level or kindergarten MA level sub-group.

Procedure

Determining entry behavior. The first step was to pretest a set of pictures and the corresponding words in order to determine which words could be taught. This step was to assess the student's entry behavior. A set of words was compiled

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[2] The cooperation of Louis Pansino, Principal and Mildred Murphy, Sally Dean, and James Swanson, teachers at Lincoln School, Urbana, Illinois, is gratefully acknowledged. The data for this study were collected and analyzed by Henry T. Lippert.

Table 1

Summary of Individual Differences in CA and Abilities (Stanford Binet MA, IQ and Peabody Picture Vocabulary MA)

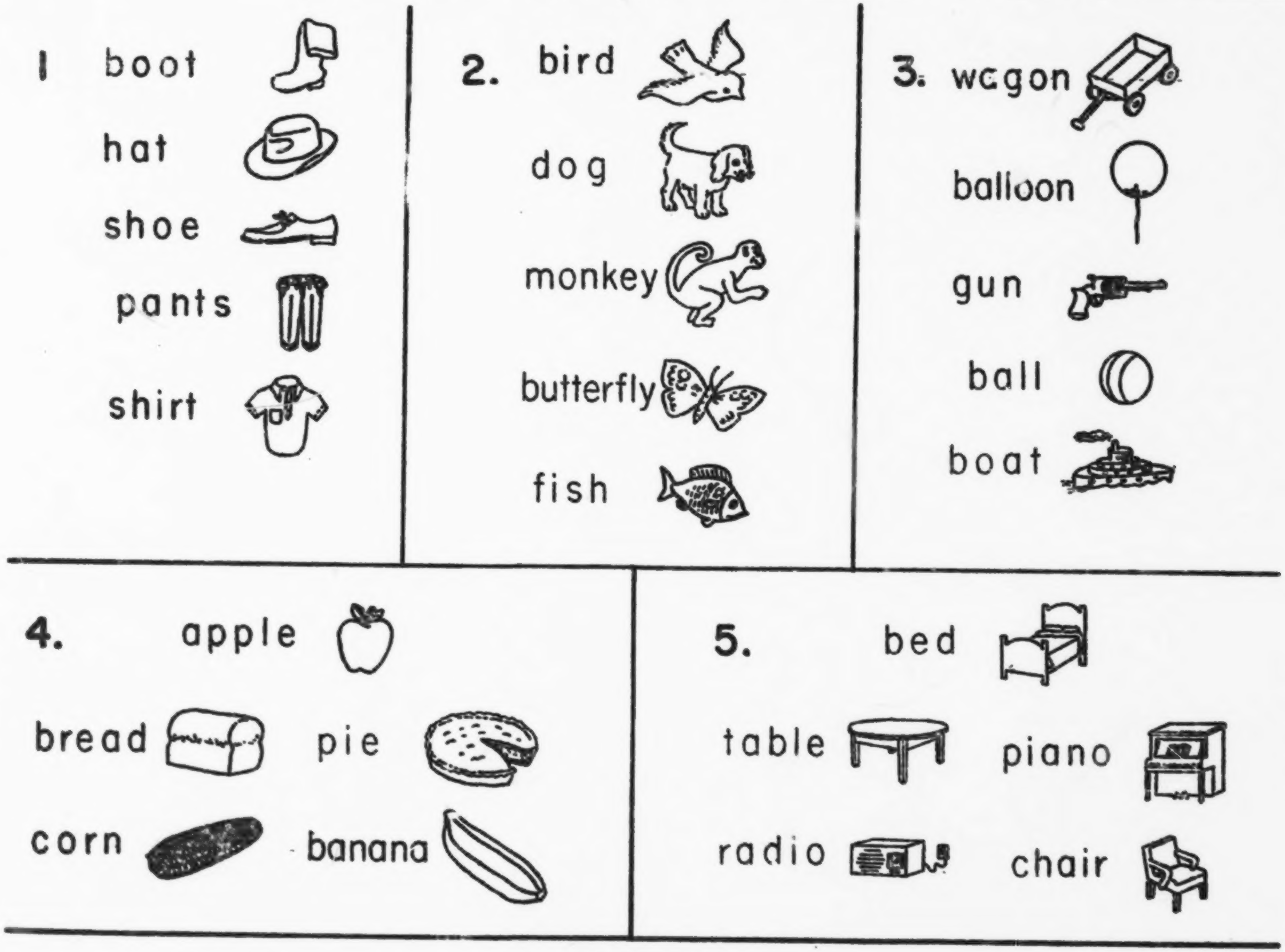
Variable	Range (mo.)	Mean	S.D.
Chronological Age (CA)	66-105	88.9	9.6
Stanford Binet MA (Form LM)	52-77	64.9	6.2
Peabody Picture Vocabulary Test MA (Form A)	39-85	59.0	7.5
Stanford Binet IQ	53-80	71.9	6.8

in a manner similar to that already mentioned with the addition of the above-mentioned criterion. Figure 1 shows this set of 25 words and the corresponding pictures used to elicit the naming responses for the words to be taught.

Presentation of materials. The original plan for this study was to use the fully automated teaching machine, BINARY (Beginning Instructor for Normal and Retarded Youngsters), to present the program. However, difficulties with its operation precluded its use for this study. Therefore, a small table top device was built, Figure 2, which stimulated the operation of BINARY, but it required an operator.

All the learning sessions were conducted in the same manner. The experimenter placed the cards containing the words to be learned in a rack (Figure 3) designed to hold the cards for teaching five words. Two sets of cards were necessary for each word, one contained cards for the Prompting S-R training, the other the cards for the Confirmation S-R training. Each set was used to get S to this assigned criterion for that word. For example, Figure 3 shows the set up for Group 1 the first time they learned any of the words (1st order of learning). The cards in Figure 3 contain the program for teaching boot, hat, shoe, pants and shirt to Group 1 for their first session. The five children in Group 1 learned these words under the same conditions and then E changed the words to bird, dog, monkey, butterfly, and fish so that Group 2 could learn their first set of words.

Every child learned the same five words in each of five concepts as illustrated in Figure 1. Neither the words nor the concepts were always taught in the same order to every child. However, each child learned all five words of


1
boot
hat
shoe
pants
shirt
2.
bird
dog
monkey
butterfly
fish
3.
wagon
balloon
gun
ball
boat
4.
apple
bread
pie
corn
banana
5.
bed
table
piano
radio
chair

WORDS TAUGHT

Fig. 1 Twenty-five words (cues) and pictures (elicitors) used in public school EMH study.

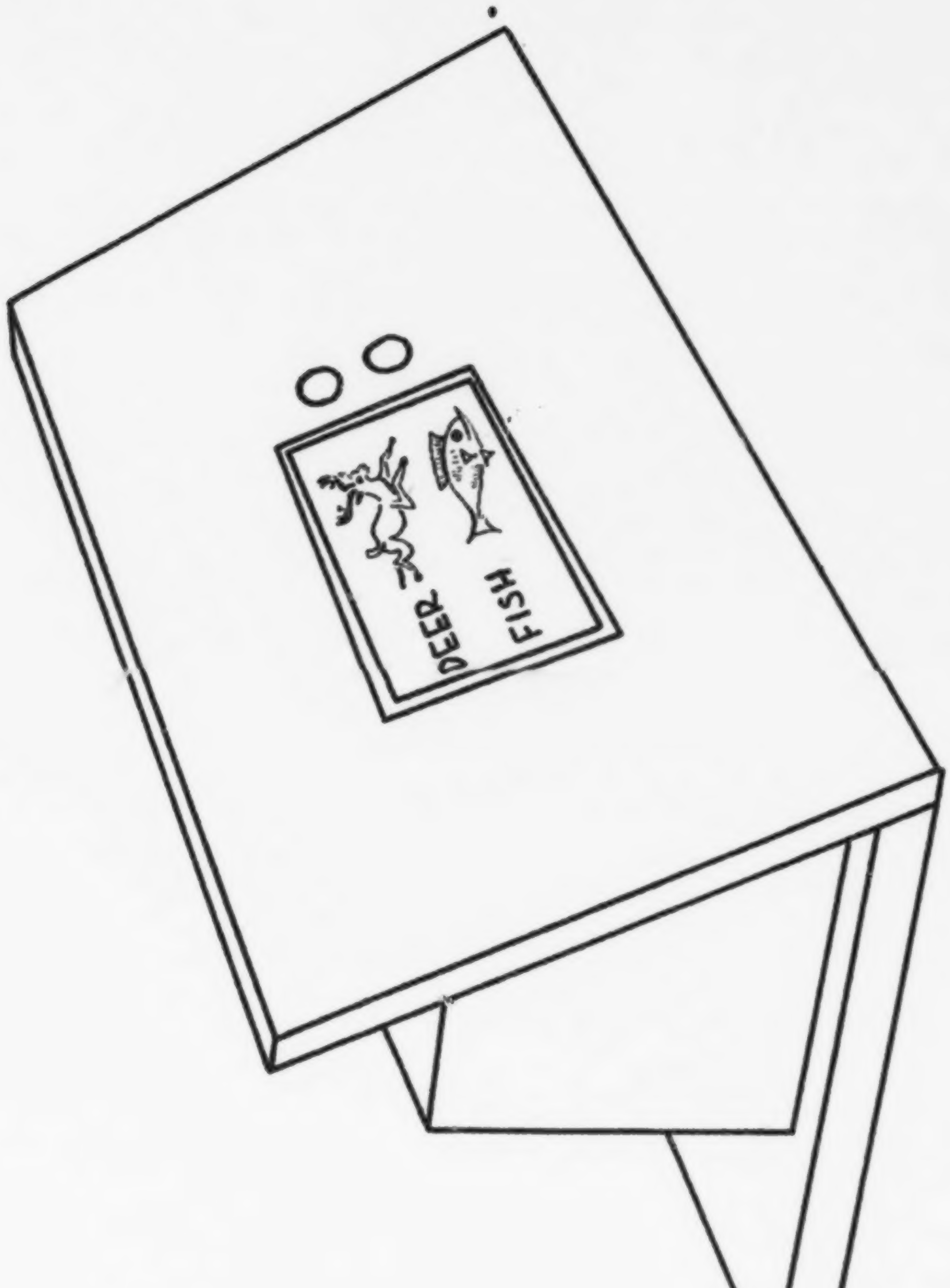


Fig. 2 Display apparatus with discrimination frame for teaching the word "fish"

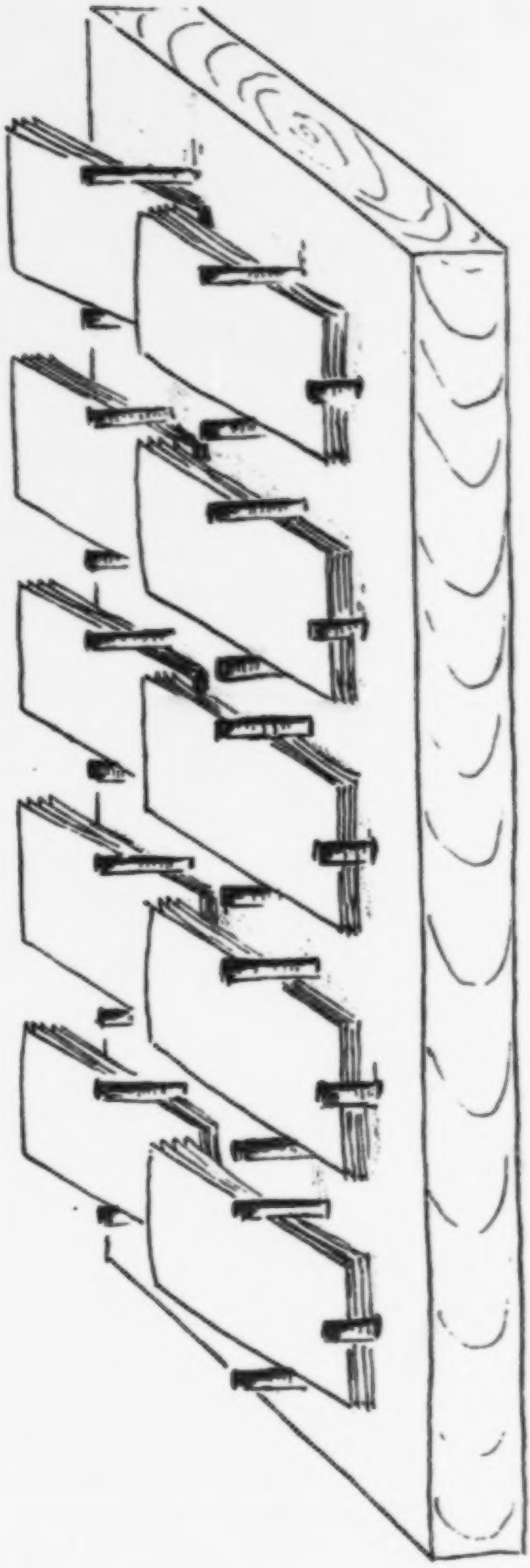


Fig. 3 Card rack for teaching five words

one concept before he started the next one. Approximately 30 minutes was required for each child to learn five words to the designated criterion level, an average of six minutes per word.

The frames of the program were reproduced by spirit duplicator on 3 x 5 cards. The child viewed each card (frame) as it was illuminated and made an overt response to the discrimination frame. In making this response, the child pressed a plastic button one inch in diameter. If the response was correct, the button was illuminated from behind. If the response was not correct, the light did not come on and the next frame was displayed. The information required by the device to determine whether or not a response was correct was carried on the discrimination card. This is accomplished by cutting off the right hand corner which is in the same half of the card as the correct answer. This missing portion of the card allowed an electrical contact to be made when the child chose the correct alternative. This circuit, when completed, lighted the pushed button. If the incorrect choice was made, the presence of the corner of the card precluded electrical contact and nothing happened. The cut-off corners were not visible from the children's position; so they could not use this to help them.

Intra-item sequencing. The sequence of these printed words and their elicitors (pictures) is the critical variable and the two sequences used are shown in Figure 4.

The Prompting S-R strategy used in this study differs from the Confirmation S-R strategy only in the arrangement of the same three frames. In the prompting sequence an S-R frame is used to prompt the student into making a correct discrimination, whereas in the confirmation sequence, the same S-R frame is used to

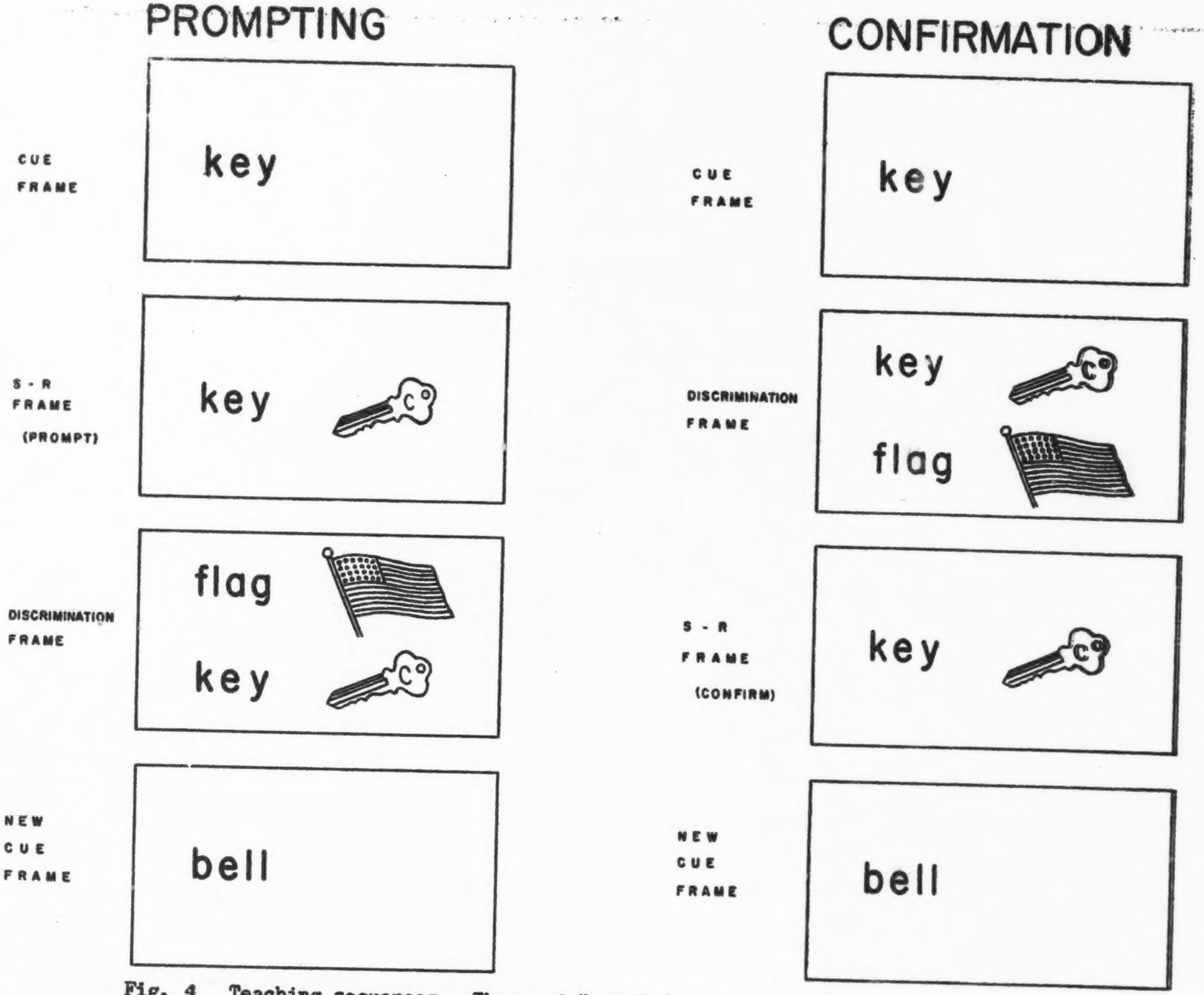

PROMPTING
CONFIRMATION
CUE FRAME
key
S - R FRAME (PROMPT)
key
DISCRIMINATION FRAME
flag
key
NEW CUE FRAME
bell
CUE FRAME
key
DISCRIMINATION FRAME
key
flag
S - R FRAME (CONFIRM)
key
NEW CUE FRAME
bell

Fig. 4 Teaching sequences. The word "bell" (frame 4) starts a new series identical to the one begun with "key". The up-down relationship of the taught word (key) with the foil word (flag) was randomized to eliminate the use of position cues

confirm a correct response (a discrimination). The same frame is used for both prompting and confirmation functions.

The behavior required of the learner may help the reader understand the differences between these sequences. In both sequences, the first frame is the cue; it is the printed form of a word which the child does not know. The display procedures are designed to make it highly probable that the child looks at this word.

In the Prompting S-R sequence the second frame pairs the cue word with a picture which is known (by the pretest) to elicit the response that is the correct verbalization of the cue word. The learner's behavior is that of responding (implicitly or explicitly) to the elicitor (the picture) in the presence of the cue (the word to be learned). Although not specifically instructed to do so, the children frequently overtly named the picture.

The last frame in the Prompting S-R sequence requires a discrimination between the word that was just presented and, therefore, is recognized and a foil word which was not just seen. An overt response to the discrimination frame was required. The learner indicated which of these two S-R pairings he had just seen (the previous S-R frame) by pressing a lucite button to the right of the frame next to the elicitor. If he chose the word being taught, a light went on behind the button. If he chose the foil word as the one he had just seen, the light did not go on and the cue frame was presented again, initiating a repetition of the same word-sequence. The light was used to minimize the interval between response and knowledge of results.

Examination of the Confirmation S-R sequence as illustrated in Figure 2 reveals that the second frame requires the overt response, and that the learner has only his memory of the printed form of the word (cue) to help him make his response. Thus, the Confirmation S-R sequence does not provide as much help to the learner in making his response. It is less prompted. If we adopt the Premack principle (Premack, 1959), the Confirmation S-R sequence provides *more reinforcement* after a correct response is made than does the Prompting S-R sequence. The frame with the pairing of the cue and elicitor follows the lighted correct-answer button. The response probability to this frame is greater than that made to the stimulus event following correct discrimination with the Prompting S-R sequence.

If the foil word is chosen, the sequence is repeated, starting with the cue frame. This is the correction procedure and it was used with both sequences. After the three frames were presented and a correct response was made to the discrimination frame, the cue frame of the next word to be taught was displayed. All responses, both correct and incorrect, were recorded.

Experimental Design

Several variables were incorporated into the experimental design. The basic interest was in the effect of various combinations of n Prompting S-R and j Confirmation S-R trials. Every word taught in this study was presented first in a Prompting S-R sequence, and then in a Confirmation S-R sequence. The question to which the design was addressed was the magnitudes of n and j. These considerations, along with those of time available per S per learning session, led to the combining of 1, 3, 6, 9, and 12 Prompting S-R trials with 1, 3, 6, 9, and 12 Confirmation S-R trials. Using each of these values of n with every value of j led to 25 combinations. One combination was a criterion of 1 correct Prompting S-R response followed by 1 correct Confirmation S-R response (designated 1-1);

this was the condition with the lowest criterion. The highest was a 12-12 condition or 12 correct responses to a word presented on Prompting S-R trials followed by 12 correct responses to the word presented on Confirmation S-R trials. There were then, 25 combinations of these two conditions.

These 25 P-C combinations, the five group assignments, five orders of learning and the 25 words learned are summarized in Table 2. The first entry in the table indicates that Group 1 learned the five words pertaining to clothes first and that they learned the word "boot" first, under a 1-1 condition, (to one correct Prompting S-R criterion trial followed by one correct Confirmation S-R criterion trial). The last entry at the bottom right indicates that Group 5 learned the words pertaining to furniture first, the word "chair" was fifth in word order and it was taught under a 3-12 criterion condition (three correct responses under Prompting S-R condition followed by 12 correct responses under the Confirmation S-R condition).

Every child learned all 25 words, each word under a unique combination of Prompting S-R and Confirmation S-R criterion conditions. All P-C combinations (teaching strategies) were used with all five groups of Ss, and for each S all five words representing a concept were learned with a different teaching strategy.

Orthogonality was not completely achieved. There were certain design variables which were correlated. Prompting, for example, was correlated with the order of the five words within concepts. The 1 and 12 Prompting conditions each appeared twice in the first order of words position for all groups. However, this lack of orthogonality was not significant as revealed by a correlation analysis of the experimental design itself. The lack of orthogonality simply meant that the

Table 2

Combinations of Number of Prompting and Confirmation (P-C) Criterion Trials Under Which Groups Learned Each Word and the Order of Learning[a]

			Group[b]				
			1	2	3	4	5
Concept	**Word**		N=4	N=4	N=4	N=4	N=3
clothes		Order	1st	5th	4th	3rd	2nd
	boot	1st	1-1	1-6	1-12	1-3	1-9
	hat	2nd	3-6	3-12	3-3	3-9	3-1
	shoe	3rd	6-12	6-3	6-9	6-1	6-6
	pants	4th	9-3	9-9	9-1	9-6	9-12
	shirt	5th	12-9	12-1	12-6	12-12	12-3
animals		Order	2nd	1st	5th	4th	3rd
	bird	1st	9-6	9-12	9-3	9-9	9-1
	dog	2nd	1-3	1-9	1-1	1-6	1-12
	monkey	3rd	6-1	6-6	6-12	6-3	6-9
	butterfly	4th	12-12	12-3	12-9	12-1	12-6
	fish	5th	3-9	3-1	3-6	3-12	3-3
toys		Order	3rd	2nd	1st	5th	4th
	wagon	1st	12-1	12-6	12-12	12-3	12-9
	balloon	2nd	3-12	3-3	3-9	3-1	3-6
	gun	3rd	1-6	1-12	1-3	1-9	1-1
	ball	4th	9-9	9-1	9-6	9-12	9-3
	boat	5th	6-3	6-9	6-1	6-6	6-12
foods		Order	4th	3rd	2nd	1st	5th
	apple	1st	12-3	12-9	12-1	12-6	12-12
	bread	2nd	6-6	6-12	6-3	6-9	6-1
	pie	3rd	1-9	1-1	1-6	1-12	1-3
	corn	4th	9-12	9-3	9-9	9-1	9-6
	banana	5th	3-1	3-6	3-12	3-3	3-9
furniture		Order	5th	4th	3rd	2nd	1st
	bed	1st	1-12	1-3	1-9	1-1	1-6
	table	2nd	12-6	12-12	12-3	12-9	12-1
	piano	3rd	9-1	9-6	9-12	9-3	9-9
	radio	4th	6-9	6-1	6-6	6-12	6-3
	chair	5th	3-3	3-9	3-1	3-6	3-12

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[a] Numbers in columns represent the required number of criterion trials correctly responded to. These are enumerated for prompting and confirmation strategies respectively.

[b] Five subjects were assigned to each group, the N's indicate the final make-up of the groups after the loss of six subjects.

number of prompting trials was not an independent measure from the order of the five words. Since the order in which the five words was presented during any session was, psychologically, not an interesting variable, it is only of a statistical interest that this relationship existed. However, as a result of this relationship, the "pure" effect of Prompting cannot be determined.

The most serious effect of this lack of independence is that, if the Prompting variable proved not to be important in the regression analysis, it could be because of this lack of independence. (The clothes and furniture words were both taught to a criterion of 1 correct response under the Prompting condition as the first word of a learning session, and the toy and food words were both taught to a criterion of 12 correct responses under the Prompting condition as this first word.)

The order of learning the words is also indicated in Table 2. This was varied so that no group of words or condition came first or last for all subjects.

Analyses of Data

The data of this study was subjected to a multiple correlation analysis using the University of Illinois IBM 7090 computer.[3] The multiple correlation analysis reveals the weightings of the independent variables which best "fit", giving the maximum prediction of each dependent variable. This relative weighting of each independent variable is indicated by its regression coefficient (the beta weights). These weightings can be either positive, negative, or zero. The magnitude and sign indicates the strength and direction of the weighting. The program in this analysis also tests the significance of these weights by dividing the regression coefficient by its standard error to yield a t score, thus testing whether the magnitude of the weight is significantly different from a weight of zero. The multiple correlation and its standard error are also calculated. The partial correlations among the dependent variables are then calculated indicating the remainder of the relationship among these variables, that is, the portion of the variance which could not be accounted for by the fit of the independent variable model.

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[3] Several attempts were made to complete the analysis on an IBM 650. Difficulties precluded completion of this analysis before the 650 was removed from use. After the University of Illinois replaced the 650 with an IBM 7090 and a program written by George Dodson of the Statistical Service Unit was available, the analysis was completed. The IBM 7090 was made available, in part, through a grant from the National Science Foundation which enabled the University of Illinois Digitial Computer Laboratory to purchase this computer. Thanks is given to H. W. Norton of the Animal Science Department of the University of Illinois for his advice and counsel in the analysis of the data.

The significant regression coefficients reveal those variables which were important in predicting the dependent variables; they indicate which variables present prior to or during learning were important determiners of the learning and retention scores.

The design was multidimensional and contained the following variables: (1) groups, (2) order of learning, (3) concept, (4) Prompting condition, (5) Confirmation condition, and (6) word order within a concept during one learning session. Since there were five levels of each of these variables in a Greco-Latin type arrangement, four curve fits could be evaluated. Thus, it was possible to evaluate the fit of linear, quadratic, cubic and quartic curves to each of these design variables.

Two alternative analyses. The variables can be divided into two sets: (a) every variable whose value was known prior to the start of the first learning session was an independent variable, and (b) every variable whose value was measured after the first learning session was a dependent variable. This division allows one to evaluate the effects of various entry levels of the independent variables on the learning that resulted. These effects are measured by the responses made by the child during the learning sessions.

It is also possible to consider the manner in which the child performed on the learning task as an independent (predictor) variable for the retention measures. Every variable of which the value was known prior to the first retention test can be treated as an independent variable with retention scores as dependent variables.

Plan of analyses. In the discussion of the results, the first analysis will deal with both learning and retention in terms of data known before the start of the experiment; therefore, the prediction of retention will be determined without using learning scores. The second analysis will predict the retention scores using the learning measures as independent variables.

Measures

Individual differences measures. Several measures of individual differences were obtained. Stanford Binet Mental Age, from Form L-M, was available for all the children. These scores were obtained from the school records and had been obtained by qualified psychological examiners. In addition, the Test of Basic Information (TOBI), The Peabody Picture Vocabulary Test (PPVT) -- and the Illinois Test of Psycholinguistic Abilities (ITPA) -- see Kirk and McCarthy 1961, were administered by personnel from the University's Institute for Research on Exceptional Children.[4]

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[4] Grateful acknowledgement is made to S.A. Kirk for his permission to use the ITPA and to Corrine Kass and Barbara Bateman for their assistance in the administration of it and to James Moss for his permission to use the TOBI and to Bert Leavitt for his assistance with the administration of it.

Word measures. There were four measures associated with the words the children learned, three were concerned with frequency of occurrence of letters; the fourth was the number of letters in the word. The frequency measures come from the tabulation of Stolurow, Jacobs and Blomme (1960). The frequencies of occurrence of letters and the letter combinations (bigrams and trigrams) was used to obtain frequency measures for the twenty-five words learned in this study. The words were ranked according to total mean frequency value using these tables. For example, the word shoe was evaluated (for the bigram rank) in the following manner: sh, 62,534; ho, 70,857; oe, 3,930; total frequency = 137,321, number of bigrams = 3, mean bigram frequency = 45,774. The mean frequencies obtained in this way for each word were ranked for all the other words, and this rank was used as an independent variable. The same process was used to obtain frequency means for the single letters, the bigrams, and the trigrams. The simple count of the number of letters in each word also was used as an independent variable. The words ranged from three to nine letters in length (see Table 3).

Learning measures. The number of trials to criterion, and the number of errors made in reaching criterion were counted separately for the Prompting S-R and for the Confirmation S-R sequences. The trials to the first anticipation, that is, the correct verbalization of the word to the printed form (the cue) before the prompt was presented and the total number of trials with correct anticipations, were recorded.

Transfer measures. The sudden withdrawal of the S-R frame, the prompt, changes the task for the learner without prior warning; and the student's response can be considered as a measure of transfer. If the learner successfully responded to the first trial under the Confirmation condition, where there was no prompt, it can be said that he successfully transferred to the changed task.

Table 3

Word Characteristics Used to Predict Learning and Retention Scores

Concept	Word	Number of Letters	Frequency Measures (Means) Single	Bigram	Trigram
Clothes	boot	4	1,017,651	45,358	1,125.
	hat	3	1,253,244	167,361	73,160.
	shoe	4	1,191,345	45,774	6,204.
	pants	5	925,387	95,863	5,397.
	shirt	5	992,789	64,533	1,936.
Animals	bird	4	621,170	23,117	782.
	dog	3	661,009	20,489	811.
	monkey	6	798,222	51,873	1,860.
	butterfly	9	818,811	60,952	9,740.
	fish	4	766,511	66,044	3,368.
Toys	wagon	5	815,709	74,636	1,613.
	balloon	7	853,694	71,413	11,251.
	gum	3	537,949	23,278	925.
	ball	4	651,634	61,002	18,616.
	boat	4	1,032,765	63,592	1,896.
Foods	apple	5	811,986	32,782	6,429.
	bread	5	920,973	90,040	13,844.
	pie	3	981,569	13,796	1,222.
	corn	4	819,269	71,239	3,597.
	banana	6	986,658	114,269	1,191.
Furniture	bed	3	845,096	43,430	1,263.
	table	5	1,056,791	38,538	5,839.
	piano	5	916,783	88,003	1,327.
	radio	5	950,116	38,475	692.
	chair	5	870,908	80,930	5,101.

Retention measures. As in the previous study, two retention measures (recall and recognition) were obtained at three time intervals, 1, 7, and 30 days, after learning. Since the previous study indicated that the recall-recognition test order did not make a difference, only one order was used in this study. The test for recall was given first.

For the recall test the printed word was presented on a card and the experimenter said: "What does that word say?" For the recognition test, five pictures of objects within a concept, including the taught word's picture and the foil word's picture were presented simultaneously in a fan shaped arrangement as illustrated in Figure 5. The child was asked to name each picture and was told the correct name if any were misnamed. The printed form of the taught word was then presented and the child was asked to indicate which picture went with the word.

RESULTS

In summarizing the results, the effect of entry levels on the learning performance will be discussed first and a discussion of what factors seem to be important in producing long-term retention of the material learned will follow. A significance level of .01 was chosen and only predictors different from zero at that level are reported as "significant."

Learning

The use of analysis of variance was precluded by the complexities of the multi-dimensional nature of the design employed and by the fact that the number of trials and errors to criterion were uniformly low. The median number of trials and errors for each of the conditions was zero, that is, in most cases the first

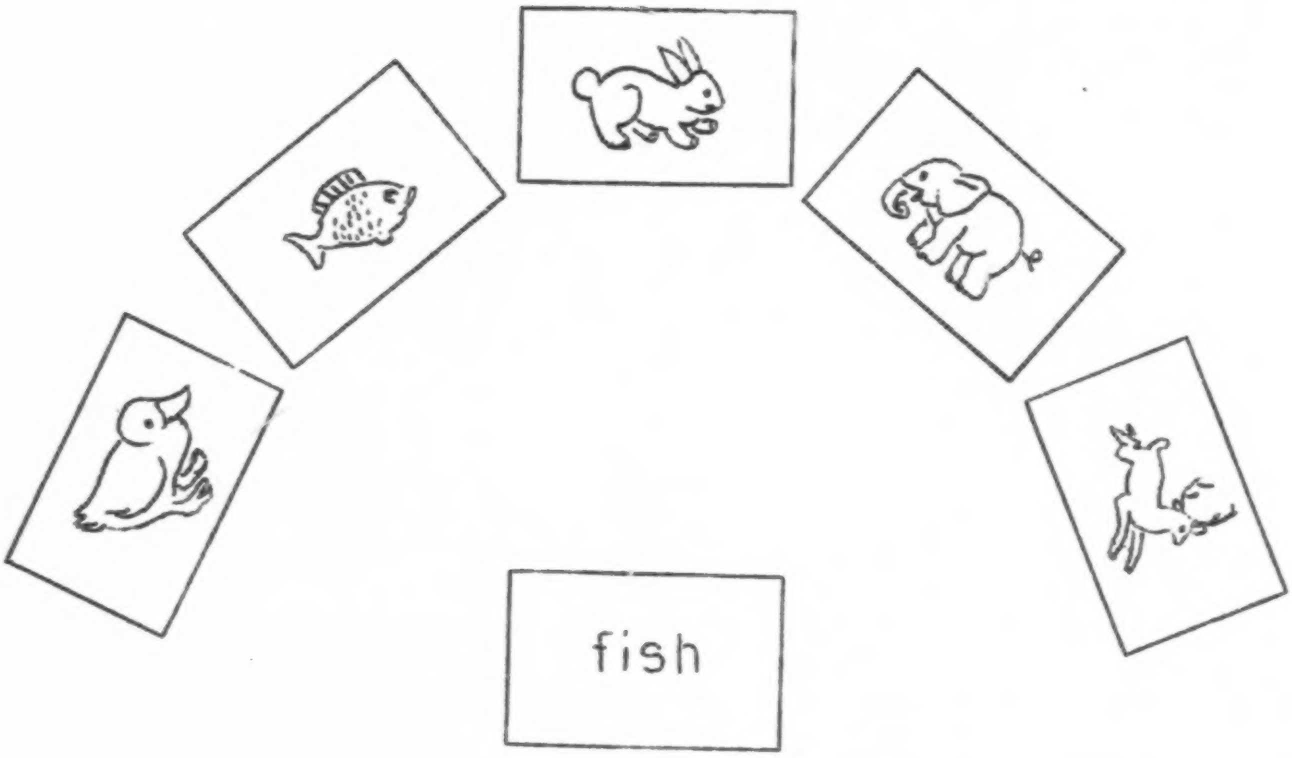

Figure 5 Retention test for recognition.

trial was the first of a series of errorless trials which continued until criterion was reached. In agreement with the first study, there were no significant differences in either trials or errors to reach the various combinations of criterion trials.

There were two types of individual measures. One type was the discrete measure--sex and race; the other was the continuous measure of ability such as provided by the Stanford Binet, The Peabody Picture Vocabulary Test, the Test of Basic Information, and the Illinois Test of Psycholinguistic Abilities.

Sex and race There were 14 males and 5 females in the final group. The variable of sex was not a significant predictor of any of the learning measures.

The variable of race had two divisions, Caucasian and Negro. There were 13 Caucasian and 6 Negro children. This variable was not a significant predictor of any of the learning measures.

Stanford Binet The mental age score was not a significant predictor of any of the learning measures. This finding indicates that the program used in this study is as efficient for children with mental ages between 4-4 and 5-5, as it is for those with mental ages between 5-6 and 6-5.

Peabody Picture Vocabulary Test The PPVT raw score was a significant predictor of learning performance under the confirmation conditions and also was a significantly predictor of the transfer from the prompting to the confirmation condition. Children who scored well on the PPVT also tended to respond correctly when the intra-item sequence was changed.

Test of Basic Information This test is composed of two parts, a non-reading portion which involves recognition of pictures common to non-school environments and a pre-reading section dealing with the recognition of signs. The summed total score was used in the present study. This score was not a significant predictor of learning performance.

The Illinois Test of Psycholinguistic Abilities. The nine subtests were separately studied as predictors of learning. Their correlation with learning was studied to determine the specific abilities that accounted for learning under the prompting and confirmation conditions.

Sub-test 1 -- decoding. Learning, under the conditions studied, did not require this ability as it was not a significant predictor of any of the measures of learning.

Sub-test 2 -- association. While this ability was not significantly correlated with trials or errors to criterion, it was a significant predictor of the number of trials to the first correct anticipation and of the total number of trials with correctly anticipated responses. The Auditory-Vocal Association Test predicted the number of trials required before the child correctly read words. The Visual-Motor Association Test predicted the number of trials that the child required to correctly read words.

Sub-test 3 -- encoding. The encoding process was apparently not significantly involved in successful performance on this learning task as it was not a significant predictor of any of the measures of learning.

Sub-test 4 -- automatic-sequencing. Neither the Auditory-Vocal Sequential nor the Auditory-Vocal Automatic ability scores were predictive of learning. However, the Visual-Motor Sequential ability scores significantly predicted three of the learning measures. Under the Prompting condition these scores predicted both the number of trials and the number of errors made. This test also was associated with the number of trials on which words were read correctly.

It is interesting to note the pattern of these results since they fit what one might assume intuitively with respect to the abilities that are required in learning under the Prompting S-R and Confirmation S-R procedures used. Measures of the ability to associate and to sequence correlate significantly but those of the ability to decode and to encode do not. Furthermore, the measures based upon the visual-motor channel for both association and sequencing correlated significantly with learning scores, and the Auditory-Vocal test predicted the number of trials on which the child correctly read the words.

Design variables. There was evidence that neither the words nor the concepts differed in the case with which they were learned. Also, neither the word nor the concept made a difference with respect to the ease of transfer from the Prompting S-R to the Confirmation S-R condition. Under each condition the number of trials required to reach criterion, the number of trials taken to first anticipate the correct response, and the number of trials required to sustain anticipatory behavior were significantly correlated with the magnitude of the criterion.

Ability measures in relation to learning. The correlation between the ability measures and the learning measures is given in Table 4. The standardized beta weights of the ability measures in predicting the learning scores are given in Table 5. The efficiency of individual differences measures as predictors of the various learning indices is indicated by the multiple correlations obtained. These are shown in Table 6. Although these multiple correlations are all significant at the .01 level or beyond, in only one case did the amount of variance which can be accounted for by the set of independent variables exceed one-half. This occured in predicting the total number of trials on which the children correctly read the words. In this case, the individual differences measures account for 57% of the variance in the learning score. For two other learning scores the individual differences measures accounted for over 20 per cent of the variance. These were trials to first anticipation and trials to criterion under Confirmation S-R procedures which is a learning measure.

Intercorrelations among learning measures. Table 7 shows the relationship among the dependent variables after the variance predicted by the independent

Table 4

Correlations of Ability Measures and Learning Measures

	Learning measures					
	Prompting		Confirmation		Trials to anticipation	Total trials anticipated-
Predictor	Trials	Errors	Trials	Errors		
Sex	-.01	-.06	.04	.02	.05	-.16
Race	.00	.04	-.12	-.10	-.01	.01
Binet M.A.	-.16	-.19	-.09	-.09	-.01	.33
TOBI	-.04	-.05	-.09	-.09	.04	.08
PPVT	-.17	-.19	-.12	-.12	-.00	.30
ITPA						
Decoding						
Auditory	-.06	-.05	-.05	-.06	.02	.23
Visual	-.11	-.07	-.17	-.15	.02	.28
Association						
Auditory-Vocal	-.07	-.12	.04	.03	.07	.23
Visual-Motor	-.13	-.16	-.05	-.05	-.03	.29
Encoding						
Vocal	-.14	-.18	.03	.01	-.01	.32
Motor	-.19	-.19	-.13	-.13	-.02	.29
Automatic						
Auditory-Vocal	-.02	-.07	.08	.06	.06	.16
Sequential						
Auditory-Vocal	-.08	-.12	.04	.04	.01	-.01
Visual-Motor	.00	.04	-.12	-.11	-.00	-.13

Note: -- $r \geq .38$, $p < .05$, df = 18.

Table 5

Standardized Beta Weights of Ability Measures in Predicting Learning Scores

	Learning measures						Transfer
	Prompting		Confirmation		Trials to anticipation	Total trials anticipated	Transfer to first C-trial
Ability Measures	Trials	Errors	Trials	Errors			
Binet M.A.	-.02	-.13	.10	.10	-.15	.08	-.09
TOBI total score	.24	.18	.16	.16	.21	.01	-.14
PPVT raw score	-.35	-.26	-.38**	-.36	-.20	.01	.41**
ITPA							
Decoding							
Auditory	-.37	-.16	-.39	-.38	-.15	-.15	.32
Visual	.38	.36	.16	.13	.13	.44	-.38
Association							
Auditory-Vocal	-.02	-.08	.01	.05	.46**	-.29	.18
Visual-Motor	.32	.26	.04	.05	-.30	.27**	-.04
Encoding							
Vocal	-.06	-.26	.49	.42	.23	.08	-.34
Motor	-.45	-.18	-.44	-.42	.01	-.00	.40
Automatic							
Auditory-Vocal	.41	.33	.26	.22	-.16	.23	-.26
Sequential							
Auditory-Vocal	.01	-.06	.17	.15	-.02	-.14	-.22
Visual-Motor	.37**	.40**	-.01	-.01	-.03	.32**	-.08

**Beta weights significantly different from zero at .01.

Table 6

Efficiency of Prediction of Performance on the Learning Task

Condition	Learning measure (dependent variable)	Multiple correlations	Standard error of estimate	Percent of variance accounted for
Prompting	Trials to criterion	.42	1.17	18
	Errors to criterion	.43	0.49	19
Confirmation	Trials to criterion	.45	4.90	21
	Errors to criterion	.42	3.17	17
Trials to first anticipation		.54	3.87	29
Total trials anticipated		.75	3.25	57
Transfer to first confirm trial		.41	0.24	17

Table 7

Inter-Correlations of Learning Measures After Variance Predicted by Independent Variables is Partialled Out

	Prompting		Confirmation		Trials to first antici-pation	Total trials antici-pated
	Trials	Errors	Trials	Errors		
Prompting errors	.80					
Confirmation trials	.03	-.03				
Confirmation errors	.01	-.03	.94			
Trials to first anticipation	.19	.04	.07	-.00		
Total trials anticipated	.08	.08	.00	.01	.01	
Transfer to first C. trial	.00	.05	-.22	-.29	.04	.94

variables was removed. High correlations in this partial correlation matrix indicate that the two variables concerned are measuring essentially the same thing. It can be seen that the measures of trials and errors within the same condition (P or C) are essentially the same measure (e.g., .80 and .94, respectively, for Prompting and Confirmation).

Anticipations. During the learning sessions an interesting transition occurred. The first successful anticipation of the prompt (i.e., correct verbalization of the cue or reading of the word) was the pivotal element for this transition. Prior to this successful reading of the word in the absence of the prompt, the children simply looked at the cue of frame 1, went on to frame 2 for which they almost always spontaneously verbalized the word when shown the cue in conjunction with the elicitor, and when the third frame appeared, made the overt discrimination response. If this overt response was correct, the button lighted and the children reacted to the correct discrimination and light as if it was reinforcing to them (i.e., they usually smiled, some giggled or said "Oh boy," etc.). At the point when the children would venture a guess as to the name of the printed word, they would find out if their overt response was correct as soon as the second frame was presented; for there the cue was paired with its elicitor. When this attempt at reading the cue word proved to be correct, the children would show signs of great delight and pleasure, (i.e., they would smile, giggle, say "I read that word!" and some would jump up and down in their chair, etc.). They showed much greater enthusiasm for the entire learning session after their first successful anticipation. Since this typically occured on the average after the second frame of the prompting procedure, the next correct response (indicated by the light behind the button) to a discrimination frame was made simply because the experimenter asked them to continue doing this part of the task. There was almost no reaction to the light behind the button after a successful anticipation. The effect of this change by the children in the portion of the task that was most reinforcing to them was that they changed the prompting sequence into a confirmation sequence with their anticipatory responses. The total number of correctly anticipated trials was the only learning performance measure which significantly predicted recall of the words. In effect, this could be thought of as practice on the recall task.

Retention

Recall and recognition. Table 8 shows the mean and median percentage of Ss who correctly recalled words after 1 day, 7 days and 30 days. As would be expected the averages are greater for recognition than they are for recall.

Learning and retention. The combined use of the learning indices as independent variables, the individual differences measures, and the design variables gives a fairly complete picture of the retention factors that enter into the reading of words that have been taught by the methods used here. In general, individual differences in ability seem to be more important factors than the experimental design variables in predicting retention. Performance during learning did not predict retention. Learning and retention appear to be quite independent of one another.

Sex and race. The sex of the child was not a significant predictor of retention scores except for recognition after one day. The child's race, however, did significantly predict retention. The Negro children remembered better than did the Caucasian children; this was true both for the recall and recognition tests at 7 and 30 days after learning. The means are summarized in Table 9. The significance levels of the beta weights assigned to sex and race are summarized in Table 10. The possibility of differences in Binet M. A. and scores obtained on the Test of Basic Information between

Table 8

Mean and Median Percentage of Children who Correctly Remembered the Words After 1, 7 and 30 days

	MA Groups					
	4-11 to 5-6 Pre School		5-6 to 6-5 Kindergarten		Total	
Retention	$\bar{X}$	Median	$\bar{X}$	Median	$\bar{X}$	Median
Recognition						
1 day	51.6	42.0	88.4	92.0	69.1	76.0
7 days	46.4	42.0	81.8	88.0	63.16	68.0
30 days	45.6	46.0	79.1	92.0	61.5	60.0
Recall						
1 day	12.8	10.0	55.1	56.0	32.84	24.0
7 days	11.6	8.0	55.6	60.0	32.4	32.0
30 days	9.6	8.0	45.3	48.0	26.5	16.0

Table 9

Mean and Median Number of Words Remembered by Negro and White Children after 1, 7 and 30 days

	Groups			
	Negro (N = 6)		Caucasian (N = 13)	
Retention	$\overline{X}$	Median	$\overline{X}$	Median
Recognition				
1 day	21.33	22.0	15.4	13.0
7 days	19.83	20.0	13.9	14.0
30 days	18.66	17.0	13.8	13.0
Recall				
1 day	6.50	6.5	9.0	7.0
7 days	7.33	8.0	8.46	6.0
30 days	6.00	5.5	6.92	4.0

Table 10

Significance Levels of Beta Weights Assigned to Sex and Race in Predicting Retention

Entry level	Measure of retention	Days since learning 1	7	30
Sex	Recall	N.S.	N.S.	N.S.
	Recognition	.01	N.S.	N.S.
Race	Recall	N.S.	.01	.01
	Recognition	N.S.	.01	.01

the Caucasian and Negro children was tested by t. The t's obtained (.9643 and .0246, respectively, see Tables 11 & 12) were far below the significance level ($t_{.025}$ = 2.11 with 17 df, two tailed test). This indicated that the groups of Negro and Caucasian children were not different as measured by these tests and that the difference in performance on retention of the sight vocabulary words cannot be attributed to differences in these basic abilities.

Mental age. Stanford Binet Mental Age significantly predicted both recall and recognition at all three time intervals after learning. This was a positive relationship indicating that children with the higher mental ages tended to retain better what they had learned. While mental age was not related to learning under these conditions of instruction, it was related to retention.

Because of the complexity of the experimental design and the fact that the repeated measures on each child were under differant (but not all) experimental conditions, there is a certain danger in selectively isolating variables out of context. The regression analysis of the complete design is needed to give the "true" picture of relationships which existed. To regroup, or to isolate, an interesting variable or set of variables violates the nature of the experimental design by unbalancing the effects of other variables.

Mindful of the dangers of regrouping to look at subsets of variables, one interesting and possible important trend is revealed in Figure 6. It shows the percentage of words, correctly recalled by the group which was at the kindergarten mental age, as the total number of criterion trials (under both P and C) is increased. There seems to be a trend toward greater efficiency in that more words are recalled with fewer practice trials when the children were required

Table 11

Binet Mental Age Differences in Relation to Sex and Race

Variable	Division	N	Mean	S.D.	t^*
Sex	Male	14	65.50	6.79	.6868
	Female	5	63.20	5.07	
Race	Caucasian	13	65.85	6.94	.9643
	Negro	6	62.83	4.62	

$^*t_{.025}$ = 2.11, df = 17; difference between means not significant at .05 (two tailed test).

Table 12

Test of Basic Information Total Score Mean in Relation to Race

Division	N	Mean	S.D.	t*
Caucasian	13	10.31	5.807	.0346
Negro	6	10.33	3.327	

*$t_{.025}$ = 2.11, df = 17; difference between means not significant at .05 (two tailed test).

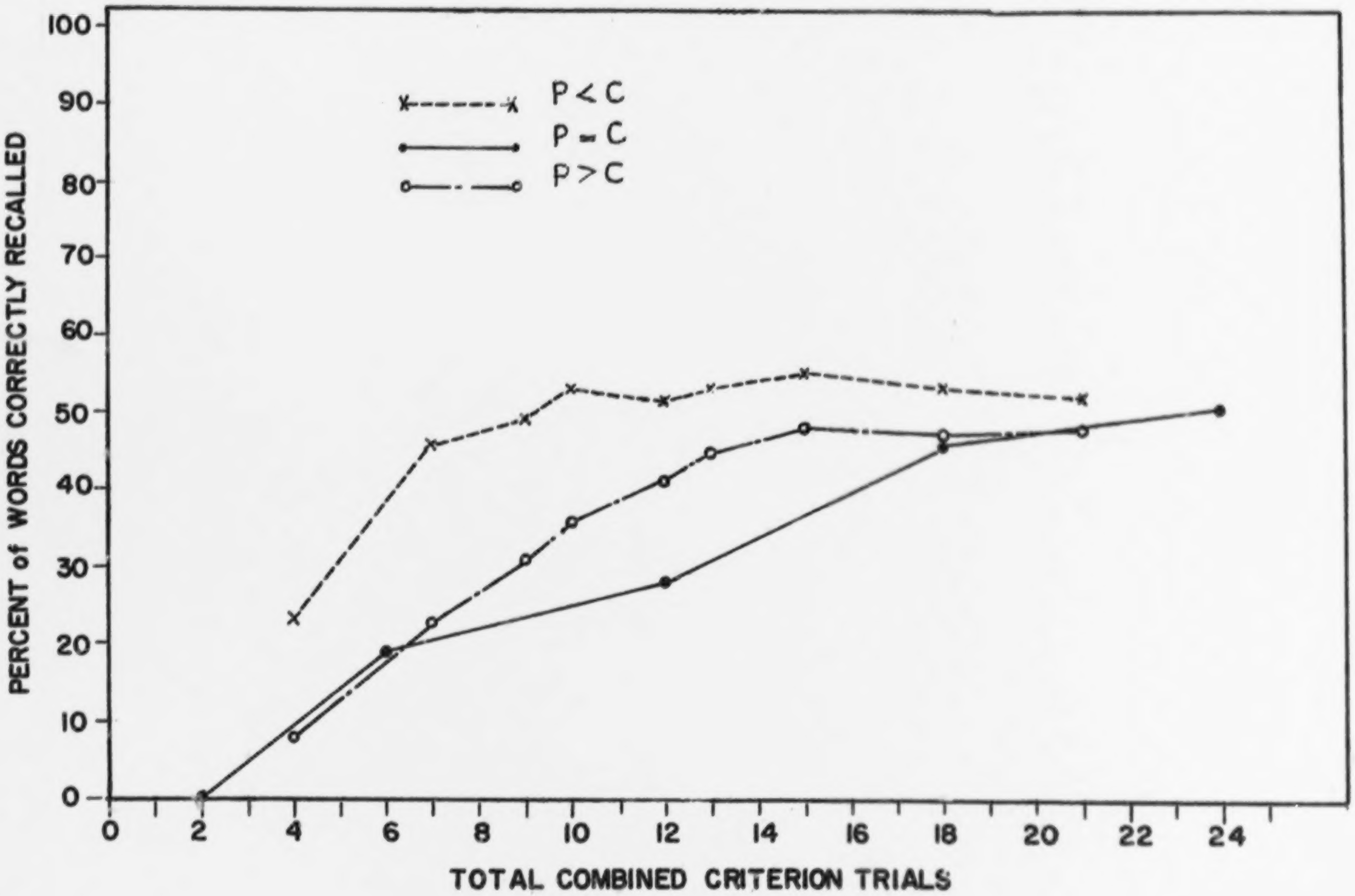

Fig. 6 PERCENT of WORDS RECALLED ONE DAY AFTER LEARNING BY THE GROUP WITHIN The M.A. RANGE of 5-6 to 6-5 .

to attain a lower criterion level for prompting than for confirmation. This curve also indicates that, on the average, it is not necessary to use P and C combinations involving more than ten or 12 trials, since an asymptote is usually reached by this time. The best number of prompting trials before changing to the confirmation sequence could not be determined by the regression analysis. A possible indicator of this number could be obtained by the mean number of trials to the first anticipation. For the entire sample this was three trials (2.97).

Peabody Picture Vocabulary Test. Performance on this test as measured with the raw score was correlated to long-term retention only after 30 days. This was a negative relationship indicating that the children who had low scores tended to retain the sight words better than those with higher scores. This was true for both recall as well as recognition scores.

Test of Basic Information. The total score on this test predicted recognition at 7 days following learning and both recall and recognition at 30 days following learning (long term). These were positive relationships indicating that with a high score on this test a child was more likely to retain the words for a long period.

The Illinois Test of Psycholinguistic Abilities. The nine subtests correlated with the recall of the sight vocabulary words, but only one subtest correlated with recognition of the words. This indicates that these psycholinguistic abilities are involved in reading words aloud, whereas in general, they are not involved in matching the printed word with its picture.

The decoding process in retention. Auditory Decoding was negatively related but Visual Decoding was positively related to recall at all three retention testing periods. Neither one was related to recognition. The former suggests that children who pronounce the word in the process of recalling it do less well than those who do not. The latter suggests that critical factor in recall is visual discrimination.

The association process in retention. Auditory-Vocal Association predicted positively the recall scores at 7 days; however, Visual-Motor Association scores predicted positively the recall scores for all three retention intervals.

The encoding process in retention. Vocal Encoding was not related to any recall measures, but it was related to recognition measures. In fact, not only was it negatively related to recognition one day after learning, but it also was the only ITPA subtest that was related to recognition. Motor Encoding, however, was negatively related to recall after 30 days.

The automatic processing in retention. The Auditory Vocal automatic processing was positively related to recall at all three retention intervals.

Sequential processing in retention. Auditory Vocal sequential processing was not a predictor of retention measures. The Visual Motor sequential processing, however, was a positively related to recall but was not related to the recognition of the words.

Retention as measured by recall and recognition are quite different processes as judged by the different abilities to which they are related. Of the ITPA test battery, Vocal Encoding was negatively related to recognition, but it was the only ITPA ability related to recognition. It seems to identify a process which some children use, although it is inefficient. On the other hand, most of the other processes measured by the ITPA were positively related to recall, i.e., Visual Decoding, Auditory-Vocal Association and Visual-Motor Association, Auditory-Vocal

Automatic processing, and Visual-Motor Sequential processing. Two processes measured by the ITPA were negatively related to recall, i.e., Auditory Decoding and Motor Encoding. These data, particularly the latter set of relationships, suggest that children who are good in sound analysis and in sound blending do not recall as well following this training as children who are less proficient in these skills. Presumably this is true because those who are more proficient use these processes whenever they can, but doing so under these conditions interferes with recall. The desirability of a follow-up study using phonic prompts seems indicated as recall following one method of training seems to be different from recall following another method. With this procedure using phonic prompts, Auditory Decoding and Motor Encoding would be expected to be positively related to recall. In other words, is it the method of training or the method of measuring retention that determines the abilities involved.

Design variables as predictors of retention. Almost none of the experimental design variables was substantially related to retention of the sight vocabulary. The beta weights were not different from zero for concepts, the number of prompting trials to reach criterion, the number of confirmation trials to reach criterion, or the order in which the words were learned. There is some evidence to suggest that the five groups of children were different in their ability to recall the words, but not in their ability to recognize the words.

The order of learning, or the learning to learn measure was significantly related to both recall and recognition, but the relationship is not consistent and seems to vary over time. One of the word characteristics was a significant predictor of one retention measure. The rank of the trigram frequency count was positively related to word recognition after one day following learning. It was easiest to recognize the words containing the most frequently appearing combinations of three letters.

Learning performance and retention. Most of the measures of performance during learning had beta weights which were not different from zero; their predictive value of the measures of retention that were used, therefore, was very small. One learning measure, however, the total number of trials on which the child correctly anticipated, was significantly related to the recall of taught words but not to their recognition.

Differences in abilities and in learning in relation to retention. The standardized beta weights of the ability measures and learning performance in predicting learning scores are given in Table 14. The multiple correlations in Table 15 reveal the efficiency with which retention of the words can be predicted. As in the prediction of the learning performance from individual differences measures of specific abilities, these multiple correlations are all significantly different ($p < .01$) from zero. However, as contrasted with prediction of learning scores, all of these correlations are higher and show less difference between the highest and the lowest. The percent of variance which can be accounted for is, in each instance, less than half. Nevertheless, none accounts for less than 35 percent. It is interesting to note that the multiple correlation with the recall scores were somewhat higher than they were with the recognition scores.

The intercorrelations among the dependent variables, after the removal of the variance related to the independent variables, are shown in Table 16. Examination of these correlations indicates that the various measures taken (recall and recognition at different times) were measuring different things. All were positive and they varied between .07 and .45.

Table 13

Correlations Between Ability Measures and Retention Scores

	Retention Measures					
	Recall			Recognition		
Ability Measures	1 day	7 days	30 days	1 day	7 days	30 days
Sex	-.15	-.12	-.08	.02	-.07	-.02
Race	-.10	-.04	-.04	.24	.23	.16
Binet M.A.	.47	.48	.39	.35	.36	.31
TOBI	.21	.24	.27	.35	.26	.25
PPVT	.43	.41	.34	.34	.34	.26
ITPA						
Decoding						
Auditory	.23	.25	.22	.20	.22	.17
Visual	.37	.38	.28	.20	.27	.24
Association						
Auditory-Vocal	.34	.32	.26	.10	.18	.15
Visual-Motor	.32	.34	.31	.25	.25	.28
Encoding						
Vocal	.35	.31	.26	.12	.19	.17
Motor	.38	.40	.33	.38 q	.35	.30
Automatic						
Auditory-Vocal	.23	.21	.17	.10	.11	.10
Sequential						
Auditory-Vocal	.11	.08	.03	.01	-.00	-.03
Visual-Motor	.07	.07	.01	.07	.08	.05

Note: -- $r \geq .38$, $p < .05$, $df = 18$

Table 14

Standardized Beta Weights of Ability Measures and Learning Performance in Predicting Retention Scores

	Retention					
	Recall			Recognition		
Predictors	1 day	7 days	30 days	1 day	7 days	30 days
Ability measures						
Binet M.A.	.41**	.45**	.45**	.41**	.50**	.53**
TOBI total score	.14	.20	.38**	.15	.28**	.47**
PPVT						
Decoding						
Auditory	-.43**	-.47**	-.59**	.03	-.24	-.40
Visual	.65**	.80**	.66**	-.20	.20	.15
Association						
Auditory-Visual	-.39	-.42**	-.25	-.15	-.07	.09
Visual-Motor	.49**	.54**	.47**	.07	.12	.25
Encoding						
Vocal	.05	-.02	.20	-.49**	-.08	.04
Motor	-.47	-.52	-.68**	.32	-.19	-.25
Automatic						
Auditory-Vocal	.44**	.51**	.46**	.22	.23	.14
Sequential						
Auditory-Vocal	.11	.15	.10	-.12	-.04	-.12
Visual-Motor	.29**	.39**	.27**	-.12	.02	.14
Performance on learning task						
Prompting						
Trials	.03	.09	.05	-.08	.06	.11
Errors	-.01	-.08	-.02	.11	-.08	-.11
Confirmation						
Trials	-.10	-.19	-.15	-.28	-.01	.06
Errors	.09	.16	.10	.25	-.05	-.10
Trials to first anticipation	.01	-.11	-.08	.06	-.05	-.08
Total trials anticipated	.16**	.21**	.27**	.14	.07	.12
Transfer to first conf. trial	.06	.09	.06	.01	.01	.01

**Beta weights significantly different from zero at .01.

Table 15

Efficiency of Prediction of two Forms of Retention of the Words Taught at Three Time Intervals

Dependent variable	Time interval	Multiple correlation	Standard error of est.	Percent of variance accounted for
Recall	1 day	.65	0.36	42
	7 days	.69	0.34	48
	30 days	.62	0.35	39
Recognition	1 day	.66	0.35	44
	7 days	.62	0.38	38
	30 days	.59	0.39	35

Table 16

Inter-correlations of Retention Measures After Partialling out the Independent Variables

Variable	Recall			Recognition		
	1 day	7 days	30 days	1 day	7 days	30 days
Recall						
1 day	---					
7 days	.45*	---				
30 days	.31	.41*	---			
Recognition						
1 day	.24	.20	.16	---		
7 days	.16	.26	.16	.33	---	
30 days	.07	.14	.20	.34	.25	---

* $r \geq .38$, $p < .05$, 18 df

Transfer

The number of Prompting S-R trials preceding the shift to Confirmation S-R did not predict transfer to the first Confirmation S-R trial. This is surprising in view of the findings with respect to the superior performance when guidance is withdrawn early.

There was strong evidence that the children learned to learn on this task. The order of their learning from their first to their last learning session was a significant predictor of most of the learning measures and also of the transfer measures. Furthermore, this was a linear relationship with respect to the increase from the first to the last measure.

The number of children who responded correctly on the first Confirmation S-R trial can be used as an index of transfer for they are making a correct response when the prompt has been withdrawn. The percentage of times a correct response was made is indicated in Table 17.

The program used in this study was shown to be an effective and efficient method of teaching sight words to children who have a mental age of 5-1/2 years or more. EMH children with an MA between 4-4 and 6-5 years can learn to read as many as 25 individual words as an average rate of one per 6 minutes of practice. However, while children with MA's as low as 4-4 years learned (MA range 4-4 to 5-5), the highest criterion level (12-12) was not sufficient to produce appreciable retention for them. The combination of Prompting S-R trials followed by Confirmation S-R trials seems to be efficient for learning since median error rates were zero and retention was 50 percent or greater whenever the number of P trials was less than the number of C trials. The use of a teaching strategy involving vanishing appeared to increase the effectiveness of the program over the use of the pure procedures and this result is in agreement with Angel & Lumsdaine's (1960) findings. However, they not only did use different prompting and confirmation

Table 17

Transfer from Prompting S-R to First Confirmation S-R Trial: Index is Proportion of Correct Responses on First Trial of Confirmation S-R

Prior P criterion	Pre School MA Group (4- to 5-6 yr)	Kindergarten MA Group (5-6 to 6-5 yr)	All Ss
1	.78	.88	.83
3	.88	.95	.91
6	.94	.95	.94
9	.96	.97	.96
12	.90	1.00	.94

procedures and a different interpretation of the basic learning process to explain their results, but they did not look at different proportions of P and C as was done here. Doing this reveals that the best retention results when the P criterion is less than the C criterion, and that the effects are about equal when the P criterion is greater than or equals the C criterion.

Contrary to common opinion (e.g., Wechin, 1962) it does not seem necessary to use a device that presents the auditory equivalent of an orthographic stimulus in order to teach mentally retarded children to emit the correct oral response to printed forms.

The experimental design used would not permit exact statistical specification of the number of Prompting S-R and Confirmation S-R trials needed to produce the best results. Since the children turned the Prompting S-R sequence into a Confirmation S-R sequence as soon as they were able to successfully anticipate the prompt, it would seem that the withdrawal of the prompt should be made response-contingent. The results show that, on the average, three trials are necessary to produce a correct anticipation and that a total of about ten trials is sufficient to produce appreciable long-term recall. This would suggest that a 3-6 or a 3-9 criterion combination of Prompting S-R followed by Confirmation S-R trials will produce a "min-max" condition, that is, the minimum time and effort for maximum retention. Another way to determine the best combination of P and C would be in terms of a curve revealing the point of diminishing returns for retention in relation to the learning criterion. The children learn-how-to-learn under the conditions used, for there is a significant increase in their performance from concept to concept. They also transfer appreciably from prompting to confirmation.

By looking at scores in terms of their predictability from knowledge of the child's abilities and performance on the task, one can observe that several interesting findings emerge. Learning score variance was primarily related to visual-motor association and automatic sequencing processes as measured by the ITPA. However, it was not related to either encoding or decoding. Children made spontaneous vocal responses during learning and these anticipatory responses were the only learning measures that correlated significantly with recall performance. Recall also was predictable using the visual-motor association and automatic sequencing scores of the ITPA, but not from either the encoding or decoding subtest scores. Multiple correlations using ability and learning measures accounted for as little as 39 percent of the variance in recall scores after 1 month, and as much as 48 percent of recall scores obtained 1 week after learning. The same aptitude measures accounted for 35% of the recognition score variance at the end of a month and 38% of the recognition scores at the end of one week. This means that an appreciable portion of retention score variance recall or recognition is not related to the ability measures used in this study nor to the design variables employed, nor to the children's performance during learning. In general, these multiple correlations are high with respect to the prediction of learning scores, e.g., those reported by Fleishman & Fruchter (1960), who attempted to predict successive stages of learning Morse Code. Their multiple correlations ranged from .29 to .59. Practically no data exist for the prediction of retention whereas those obtained in this study for recall varied between .62 and .69, and for recognition between .59 and .66. These correlations favorably compare with those reported for learning scores.

SUMMARY

This study was an extension of previous research using Prompting S-R and Confirmation S-R procedures to teach a sight vocabulary of 25 nouns to 25 educable mentally retarded subjects. A battery of ability tests was administered before learning, and characteristics of the words also were secured to use as predictors of learning, retention, and transfer. Twenty-five conditions of vanishing (Prompting S-R followed by Confirmation S-R) were used, one with each word learned.

During learning, the programs had median error rates of zero. Retention, measured by both recall and recognition tests after 1 day, 7 days, and 30 days, was appreciable and appeared to be optimum when the criterion for Prompting S-R was below that for Confirmation S-R. From these data, the estimate of the optimum combination of learning criteria for Prompting S-R followed by Confirmation S-R for EMH children so as to maximize their retention of a sight vocabulary is between a 3-9 and a 6-9.

Multiple and partial correlational analyses were used to determine the abilities involved in learning, retention, and transfer. The percentage of variance in retention scores accounted for by the set of predictor variables (abilities, word characteristics, and learning scores) varied from 35 percent (recognition scores after 1 month) to 48 percent (recall scores after 1 week). Visual Motor association and Automatic Sequencing processes measured by the ITPA were the best predictors of learning and retention scores. Children made spontaneous vocal responses while learning, and these not only correlated significantly with recall scores but also appeared to be a useful basis for specifying a response contingency for the vanishing of prompts on an individual basis.

Chapter 7

INDIVIDUALIZED USE OF AUTHOR I: A CLINICAL APPLICATION OF A COMPUTER-PREPARED PROGRAM[1]

AUTHOR I, written in SPS, uses the console typewriter of the 1620 or the card punch to out-put the learning material which it generates. As in-put it uses three types: (1) sentence forms; (2) lists of words designated as objects, attributes, verbs and modifiers; and (3) sentence codes. The program interprets the sentence codes, selects a sentence form and inserts words as the variable elements into the sentence forms. It can, if called for, perform some grammatical corrections and vanishing operations which could be any rule for eliminating portions of the variable elements of the sentence (e. g., the last letter of a word, then the second to last letter, etc.). There are two optional modes of use: (a) printed or punched out-put or (b) simulation of an on-line teaching system. The former is used to prepare materials for off-line applications which are in the format of a linear program with blanks to be filled in by a student and so located on the page that they can be inserted in the typewriter for a different mode of presentation to the student. The latter is accomplished by having the student sit at the console typewriter and observe the out-put as it is prepared. The typewriter is programed to stop at points where the student is to respond. Once a student responds, the system interprets the response, displays the result of a comparison with an expected standard and prints out a message indicating correctness or incorrectness of the student's response and then goes on to display the next frame of material.

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[1] The data were collected by Peggy S. Mooney, educational programer and therapist.

One use of the AUTHOR I computer program is to generate learning materials organized on a specified basis and presented to the student in programed learning format typical of the constructed response type.

The off-line application of the program is particularly desirable when the out-put can be a stencil for mimeographing materials to present to students, all of whom require the same materials. A still more interesting application occurs when the out-put of the typewriter is generated uniquely for an individual student. One case of this exists when the general logic of instruction, or the instructional strategy, is to be the same for all students who differ, however, in their particular needs for practice. For example, students may need spelling practice but may differ in the kinds of errors they make. They would, perhaps, be differentially benefited by the presentation of different sets of words. Similarly, the students with reading disabilities may show particular patterns of disability (e.g., encoding), suggesting that each of them could benefit by the same instructional strategy but the materials best used for each of them may differ. One child who has a motor encoding deficiency may need second-grade material and another with the same deficiency may need fifth-grade material.

PROBLEM

The present study was an attempt to individualize the use of AUTHOR I for the purpose of meeting the unique requirements of a child who had sufficiently severe learning disabilities to have been passed from teacher to speech therapist to psychologist. For this particular application of AUTHOR I the words were specified to meet the particular requirements of the child and a general code was written for the sentence forms to generate a unique set of materials for his disability. The Illinois Test of Psycholinguistic Abilities (ITPA) revealed that the child had a severe encoding deficit. Consequently, the codes for sentence forms and vanishing were prepared for this problem. His test results are summarized in Table 1; they indicate that he was at least average in his general intellectual ability. He was unable, however, to express language either motorically or vocally. He was also unable to make multiple associations to simple words even when given an example. He was able for instance to use a single characteristic describing "apple" as in the phrase . . . A red apple . . . but was unable to expand this idea of apple, giving alternative characteristics such as would be the case in the phrase . . . A round, red apple. He had no flexibility of responses, and alternative responses to a single problem were not possible. He could memorize a 14-line poem and recite it from memory. His comprehension and storage of material, if assessed by requiring only a "Yes" or "No" answer, was superior.

The child, in addition, did not have a conception of hierarchical associations or of the existence of categories. Everything appeared to be a separate entity to him; relationships between phenomena were not linked although facts were stored. His problems appeared to be one of associative organization for storage, or of retrieval and expression.

The educational therapist felt that this child needed a small-step program with carefully-controlled vocabulary and sequencing. Our feeling was that he also needed very carefully controlled practice in expressive behavior under precise stimulus control and with an obvious associative pattern or structure. This was a set of requirements for remediation which suggested the potential

Ability Measures on the Child who Received Programed Instructional Materials Generated by AUTHOR I

Pre-Training

Wechsler Intelligence Scale for Children (vocabulary test omitted)	CA 9-11
Verbal	IQ 118
Performance	IQ 114
Full Scale	IQ 117
Ravens Progressive Matrices I	CA 9-11
IQ Equivalent	113
Goodenough Draw-A-Man (12-63) (motor encoding task)	CA 9-11
	IQ 73
	MA 7-3
Peabody Picture Vocabulary Test	CA 9-11
	IQ 128
	MA 9-4
California Achievement Test (elementary) (9-63)	CA 9-8
Reading Vocabulary	2.0
Reading Comprehension	3.4
Arithmetic Fundamentals	3.2
Arithmetic Reasoning	3.0
Language Mechanics	3.4
Informal speech test	No errors

California Mental Maturity (10-63)	
IQ	99
Non-Language IQ	116
Language IQ	82

Post-Training

Ravens Progressive Matrices I	CA 10-10
IQ Equivalent	119
California Achievement Test (elementary) (9-64)	CA 10-8
Reading Vocabulary	2.3
Reading Comprehension	3.5
Arithmetic Fundamentals	4.5
Arithmetic Reasoning	5.0
Language Mechanics	3.7
Informal speech test	No errors

value of AUTHOR I. This student appeared to be one who could be helped by programed instruction in reading. An approach very different from classroom instruction was desirable because of prolonged resistance and defeat in that environment. Integration of the motor and vocal areas was defined with the educational objective of teaching the concept of roundness. A sample of the programed sentences used with the boy are presented in Figs. 1 and 2. Figure 1 shows sentences used early in the program. Figure 2 shows sentences to which the child was required to respond with multiple attributes. Each figure represents the number of sentences used in one session.

The six sentence forms used to generate his materials were:

a) A(n) 0 can be a A thing.*
b) Some 0(s) are A things.
c) A(n) 0 is a A thing.
d) Some A things are 0(s).
e) A(n) A thing often is a(n) 0 .
f. A(n) A thing can be a(n) 0 .

*Note: 0 = object word and A = attribute word;
(n) indicates the change from a to an;
(s) indicates the plural form.

The mode of presentation of these sentences was to have the child place the page in a standard typewriter. He then turned the platen until the sentence came into view. After reading the sentence, he typed the response word(s) above the dashed lines. Once he had made his constructed response, he rolled the platen forward into view and compared his answer with the correct one. A

A STONE CAN BE A ROUND THING.

ROUND

AN APPLE CAN BE A ROUN* THING.

ROUND

A BASEBALL CAN BE A ROU** THING.

ROUND

SOME GRAPES ARE RO*** THINGS.

ROUND

A BUTTON OFTEN IS A R**** THING.

ROUND

A BEET CAN BE A ***** THING.

ROUND

Fig. 1. Sentences used early in the program.

SOME ROUND,PURPLE THINGS ARE GRAP**.

GRAPES

A ROUND,LONG THING OFTEN IS A CHA**.

CHALK

A ROU**, PURP** THING OFTEN IS A GRAPE.

----- ------

ROUND PURPLE

SOME ROU**, LO** THINGS ARE CHALKS.

----- ----

ROUND LONG

SOME ROU**, FL** THINGS ARE BUTTONS.

----- ----

ROUND FLAT

Fig. 2. Sentences used late in the program.

portable tape recorder was used simultaneously to involve the vocal encoding channel. The child read each sentence, each word he typed, and the sentence with the word filled in, and then listened to himself (see Fig. 3 for the step-by-step flow chart of remediation procedure and Table 2 for the orderly progress of the program's schema).

RESULTS

The results obtained with this use of AUTHOR I were encouraging. The child enjoyed the sessions with the therapist and looked forward to this part of his lesson. He became adept at typing the words and the time involved decreased, indicating that his ability to express himself (encoding) had increased. When the sessions began, this boy was almost unable to express himself. In the school classroom, he had raised his hand voluntarily but, when called upon to respond, had remained silent for as long as the teacher would wait. He was also unable also to express himself adequately in writing.

When he returned to school in the fall, after having received the AUTHOR I generated materials during the spring and summer, he had a new reading teacher. She reported that he answered questions verbally using one or two-word sentences. In committee work he talked freely with classmates and often supplied ideas.

The change in the encoding scores (shown in the ITPA test results in Table 3 and Fig. 4)is dramatic. It cannot, of course, be said that this change is totally a result of exposure to the programed materials. The AUTHOR I materials, however, were undoubtedly beneficial since everything prior to their use had been unsuccessful in producing any change in the child's ability to encode.

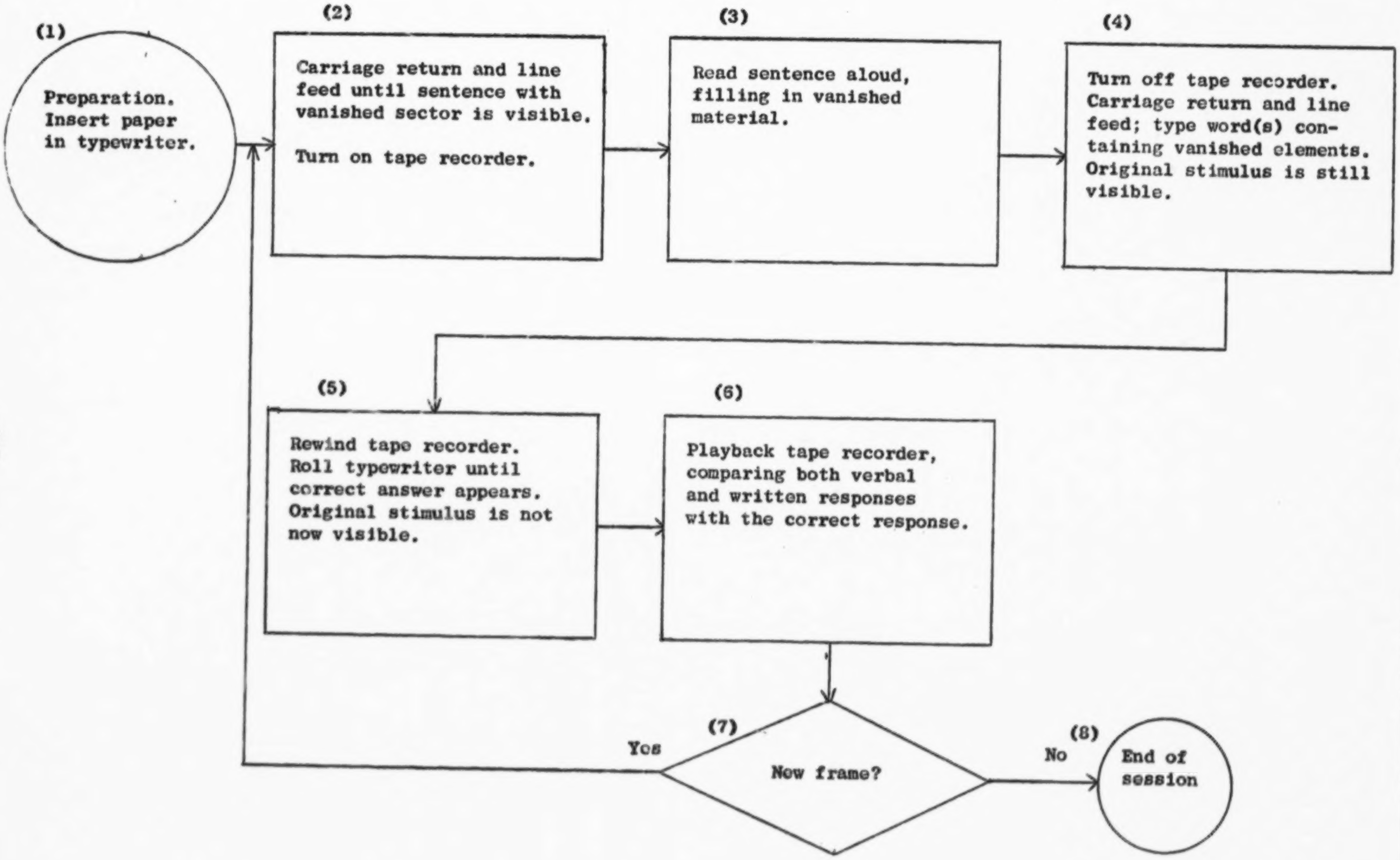

(1)
Preparation. Insert paper in typewriter.
(2)
Carriage return and line feed until sentence with vanished sector is visible.
Turn on tape recorder.
(3)
Read sentence aloud, filling in vanished material.
(4)
Turn off tape recorder. Carriage return and line feed; type word(s) containing vanished elements. Original stimulus is still visible.
(5)
Rewind tape recorder. Roll typewriter until correct answer appears. Original stimulus is not now visible.
(6)
Playback tape recorder, comparing both verbal and written responses with the correct response.
(7)
New frame?
Yes
No
(8)
End of session

Figure 3. Flow chart of remediation procedure.

Table 2

Step-by-Step Schema of the Vocal-Motor Encoding Program

Step	# of attributes[a]	order[b]	word vanished[c]	vanishing pattern[d]
I	1	O-A	A	1 - 5
II	1	A-O	A	1 - 5
III	1	O-A	O	2, 5
IV	1	A-O	O	2, 5
V	2	O-A	A	4, 5
VI	2	A-O	A	4, 5

[a] Number of attribute words appearing in each sentence.

[b] Order in which the object and attribute are presented.

[c] Word in which the vanishing takes place.

[d] The step-size of vanishing: 1 - 5 means that one letter at a time is vanished; 2, 4 means that first 2 and then 4 letters are vanished at a time; similarly for 4, 5.

Table 3

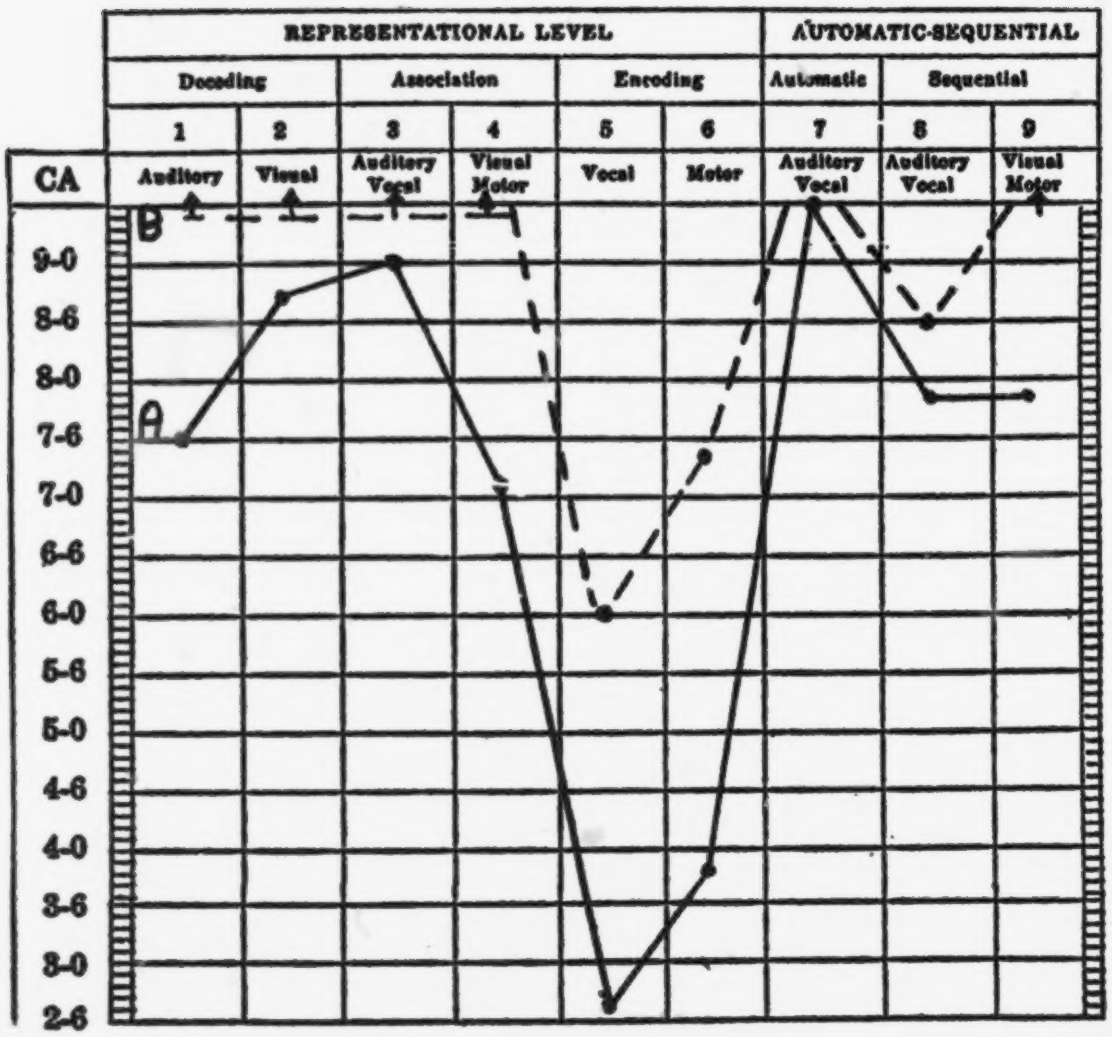
Illinois Test of Psycholinguistic Ability

Language Age Prior to and Subsequent to the Use of Programed Instructional Materials With One Subject

Subtest	Pretest Age*	Posttest Age*
Decoding		
Auditory	7-6	**AN
Visual	8-9	**AN
Association		
Auditory-Vocal	9-0	9-0**AN
Visual-Motor	7-2	**AN
Encoding		
Vocal	2-7	6-0
Motor	3-10	7-4
Automatic		
Auditory Vocal	9-6	**AN
Sequential		
Auditory Vocal	7-10	**AN
Visual Motor	7-10	**AN

*Pretest C. A. was 9-11, Posttest C. A. was 10-10

**Indicates that he achieved the maximum score.



KEY

A Pre-Remediation, CA 9-11.
B Post-Remediation, CA 10-10.

Fig. 4 ITPA profile for Tommy, a reading disability case treated with a program generated by Author I, SOCRATES.

IMPLICATIONS

Although this use of AUTHOR I to generate instructional materials involved only one child, the results were encouraging. Further uses of AUTHOR I for supplying materials for individual instruction are possible.

The use of an on-line typewriter or a Cathode Ray Tube Display with a Keyboard under computer control would be the most desirable way to present materials generated by such a computer program. Under such a condition the computer could adapt the educational program to the student's responses. Progression of the frames from minimal change to maximal change, for example, would be handled individually in reference to a particular child's needs. If he made more errors than expected for instance, the rate of change could be slowed down. If he made fewer errors than anticipated, the change could be speeded up. The use of a digital computer for teaching in this manner could achieve a relatively high degree of adaptivity to a student's specific needs.

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